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AUTHORITY

USAWC ltr, 16 Sep 1969

THE HENRY SOUTHER ENGINEERING CO
HARTFORD, CONN.

Report

to

Commanding Officer
Springfield Armory
Springfield, Mass.

on

INVESTIGATION OF SALT SPRAY METHOD OF TESTING CORROSION RESISTANCE
(Contract DA-19-058 ord. 652)

Report No. 3

Submitted by

The Henry Souther Engineering Co.
Hartford, Conn.

By ______________________

May 7, 1952

Objective

Phase III, which is covered in this report, was to carry out the detailed research and test program developed in Phase I, using equipment developed and standardized in Phase II.

Summary

Twenty-four separate tests were carried out in accordance with data outlined in Phase I as follows:

Test No. 1 was conducted to determine the rate of corrosion of steel panels in various locations in the salt spray cabinet.

Test No. 2 was a repeat test on the corrodibility at various locations.

Test No. 3 was made to determine the effect of nozzle pressure on the rate of corrosion.

Test No. 4 was made to determine the rate of fog collection at various locations in the salt spray cabinet.

Test No. 5 was made at 95°F, 20% sodium chloride solution, using steel panels only, to determine the effect of test location.

Test No. 6 was a 200-hour salt spray test run under the following conditions: 20% sodium chloride solution, pH 7.0, temperature 100°F.

Test No. 7 was run under the following conditions: 20% sodium chloride solution, pH 7.0, temperature 95°F.

Test No. 8 was run under the following conditions: 20% sodium chloride solution, pH 7.0, temperature 70°F.

Test No. 9 was run under the following conditions: 20% sodium chloride solution, pH 7.0, temperature 90°F.

Test No. 10 was run under the following conditions: 10% sodium chloride solution, pH 7.0, temperature 95°F.

Test No. 11 was run under the following conditions: 5% sodium chloride solution, pH 7.0, temperature 95°F.

Test No. 12 was run under the following conditions: 5% sodium chloride solution, pH 7.0, temperature 70°F.

Test No. 13 was run under the following conditions: 20% sodium chloride solution, pH 6.0, temperature 95°F.

Test No. 14 was run under the following conditions: 20% sodium chloride solution, pH 8.0, temperature 95°F.

Summary Cont'd

Test No. 15 was run under the following conditions: substitute ocean water, pH 8.2, temperature 95°F.

Test No. 16 was run under the following conditions: 20% sodium chloride solution containing 0.1% sodium iodide, pH 7.0, temperature 95°F.

Test No. 17 was run under the following conditions: 20% sodium chloride solution, pH 7.0, temperature 95°F, with the particle size of the fog reduced from 0.5 micron (used in all other tests) to 0.1 micron.

Test No. 18 was run under the following conditions: distilled water, pH 7.0, temperature 95°F.

Test No. 19 was a repeat test using 20% sodium chloride solution, pH 7.0, temperature 95°F.

Test No. 20 was made to determine the effect of corrodibility by varying the angle of the specimens tested.

Test No. 21 was made to determine the effect of lowering the surface tension of the 20% sodium chloride solution by the addition of 0.1% Aerosol OT when run at pH 7.0 and 95°F.

Test No. 22 was an outdoor exposure test conducted on Long Island Sound within 150 feet of high water.

Test No. 23 was an outdoor exposure test conducted on the roof of the laboratory building.

Test No. 24 was a humidity cabinet test, using a relative humidity of 95% at 100°F.

A statistical study has been made of the results obtained and is given in the Appendix of each test.

TEST NO. 1

Object

The object of this test is to compare the corrosion rate of test specimens at the various locations within the salt spray cabinet.

Summary

Tests have been conducted to determine if steel panels will corrode at a more rapid rate due to their particular location in the salt spray test cabinet. This is a necessary preliminary step before the rate of corrosion of different metals can be measured with sufficient accuracy.

Introduction

The purpose of this phase of the investigation was to locate any "hot-spots" in the salt spray cabinet. "Hot-spots" in this case designate those areas where, due to their relative location in the cabinet with respect to the atomizer or for any other reason, panels of like material will corrode more rapidly than panels in another location.

Procedure

Thirty-six low-carbon, steel panels, measuring 2" x 3" were abraded on both sides using 240 grit cloth and an oscillating electric sander. The panels were numbered consecutively with stamped numerals and were cleaned in acetone, followed by A-1 cleaner solution at 160°F and a hot water rinse. The panels were then free from "water break." After drying in a forced air oven at 110°C, they were desiccated over calcium chloride, cooled to room temperature and weighed to the nearest tenth of a milligram. Each panel was placed in an individual paraffined wooden rack so slotted as to incline the panels at approximately 15° from the vertical. These holders and panels were arranged on a large wooden rack in the salt spray cabinet in nine rows of four each according to a previously determined random distribution of 36. All wood parts had been previously coated with paraffin.

The atomizing nozzle was directed away from the panels and against the side wall of the box so that any spray falling on the panels had been previously reflected from the wall. This was done to provide a more even distribution of fog in the cabinet. Distilled water was used to generate the fog, and the temperature of the box was maintained at 95°F. A summary of the additional operating conditions is shown in Appendix A. After periods of 24 hours, corresponding to the 1st, 2nd, 3rd, 4th, 5th and 8th day, the panels were removed from the box and were scrubbed thoroughly under running water with a stiff nylon hand brush. The panels were then dried at 100°C, desiccated and weighed as before. The individual weights and times of exposure are also shown in Appendix A. The position of the individual panels in the box is shown in Appendix B. From the data compiled, the average weight loss, the standard deviation and the control limits were computed, and also appear in Appendix A.

A grouped frequency distribution chart, a control line chart, a plot showing the amount of corrosion with respect to position in the box and a graph correlating the percentage of the total amount corroded with the day, were also constructed and are shown in Appendix C.

Discussion

The grouped frequency distribution chart in Appendix C indicates that the values of the individual weight losses group themselves around the average in a normal manner and in accordance with the conventional "bell-shaped" distribution curve.

The control chart method of analysis provides a criterion for detecting lack of statistical control of quality and is used for determining when observed variations in quality are greater than should be left to chance. The control limits used are plus and minus three times the standard deviation as suggested by the ASTM as a criterion for action to look for assignable curves of variation. This chart shows that the results generally fall within the control limits and are fairly evenly distributed between them. Since, however, certain values are outside the limits, it is indicated that there is a variation in results that cannot be attributed solely to chance.

The plot depicting the amount of corrosion (weight loss) with respect to the position in the salt spray cabinet shows that there is a tendency toward a greater amount of corrosion in the side of the box nearer the exhaust and a smaller amount of corrosion nearer the nozzle and along the front of the box. It is interesting to note that the two panels showing the least amount of corrosion were those on the two corners nearest the nozzle.

The graph correlating the percentage of the total amount corroded with the day shows that the corrosion rate was not constant but rose gradually to a maximum on the third day and then decreased to a minimum on the eighth day.

Conclusions

There is a definite gradation of the rate of corrosion with the greatest amount of corrosion occurring in those areas farthest removed from the nozzle and the plate glass window in the front of the cabinet.

Note: The A-1 cleaner mentioned above is made in accordance with Springfield Armory Tentative Laboratory Specification LS-5, dated March 23, 1950. The suggested composition of this alkali cleaner is as follows:

Sodium Carbonate, Soda Ash, Anhydrous Fed. Spec. O-S-571	32.8%
Trisodium Phosphate, Tech. Fed. Spec. O-S-671	47.2%
Non Ionic Surface Active Agent	5.2%
Anionic Surface Active Agent	14.8%

APPENDIX A

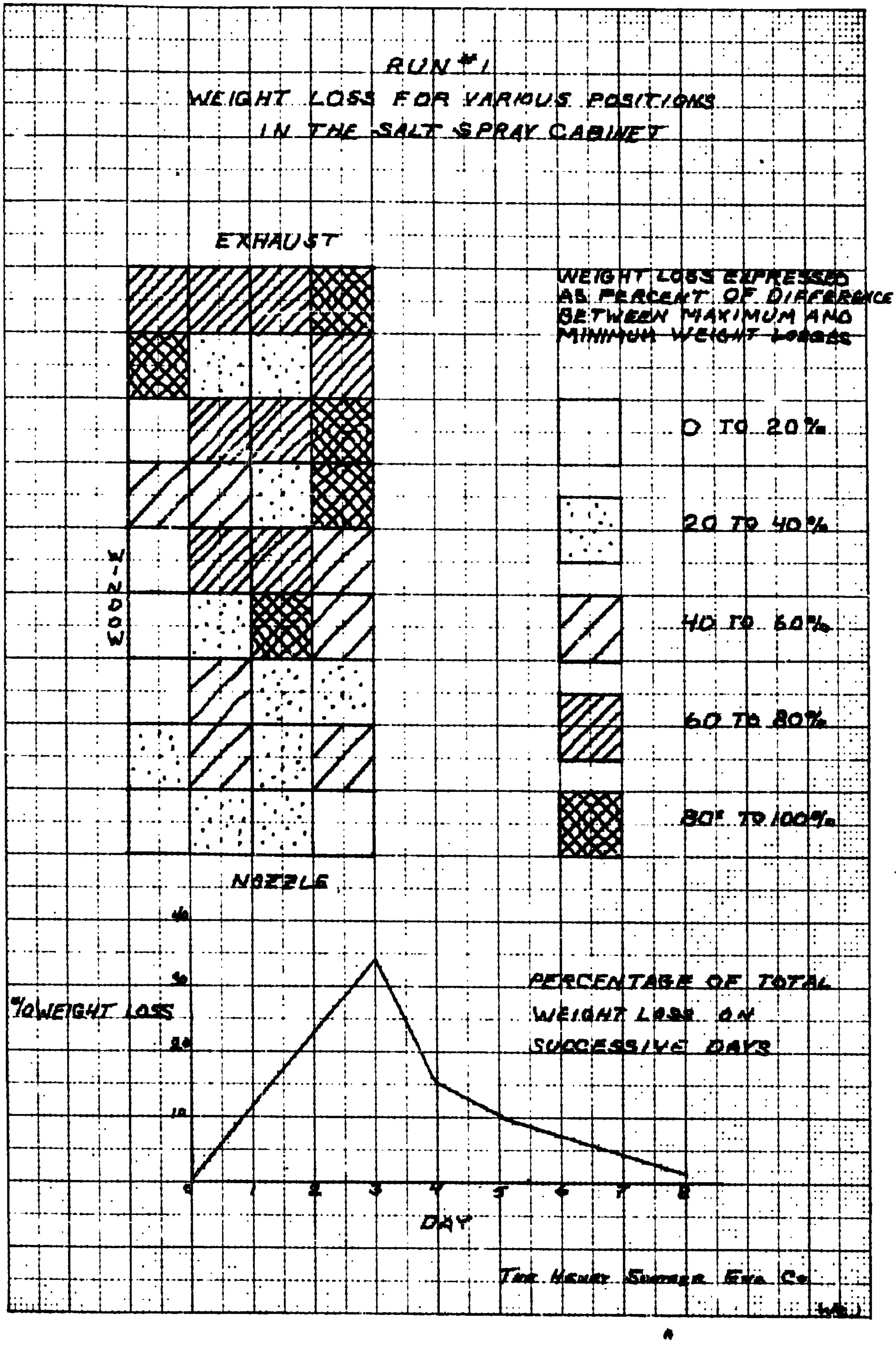
COMPARISON OF CORROSION RATES AT VARIOUS TEST LOCATIONS

TEST NUMBER I

HOURS	9/21/51	9/25/51	9/26/51	9/27/51	9/28/51	10/1/51
Solution Composition.	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O
Dry Bulb Temperature. (° F.)	89°	100°	98°	95°	98°	98°
Wet Bulb Temperature. (° F.)	89°	100°	98°	96°	98	98°
Relative Humidity.	100%	100%	100%	100%	100%	100%
Particle Size. (microns) Av.	.3 - 2.0	.3 - 2.0	.3 - 2.0	.3 - 2.0	.3 - 2.0	.3 - 2.0
Rate of Settling. (mm./sec.) Av.	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
Air Pressure. (lbs./in.^{2})	14	14	14	13.8	14	16
Air Temperature. (° F.)	83°	95°	98°	95°	95°	95°
Rate of Flow. (ft.^{3}/minute)	.15	.15	.15	.15	.15	.15
pH of Solution.	6.0	6.0	6.0	6.0	6.0	6.0
pH of Fog.	6.0	6.0	6.0	6.0	6.0	6.0
Rate of Fog Collection. (ml./hour)	1.63	1.48	1.04	1.50	1.32	1.42
Impurities in Salt Solution. 1.Assay 2.Br and I 3.Heavy Metals	—	—	—	—	—	—
Specific Gravity of Solution.	—	—	—	—	—	—
Volume of Solution in Reservoir.	—	—	—	—	—	—

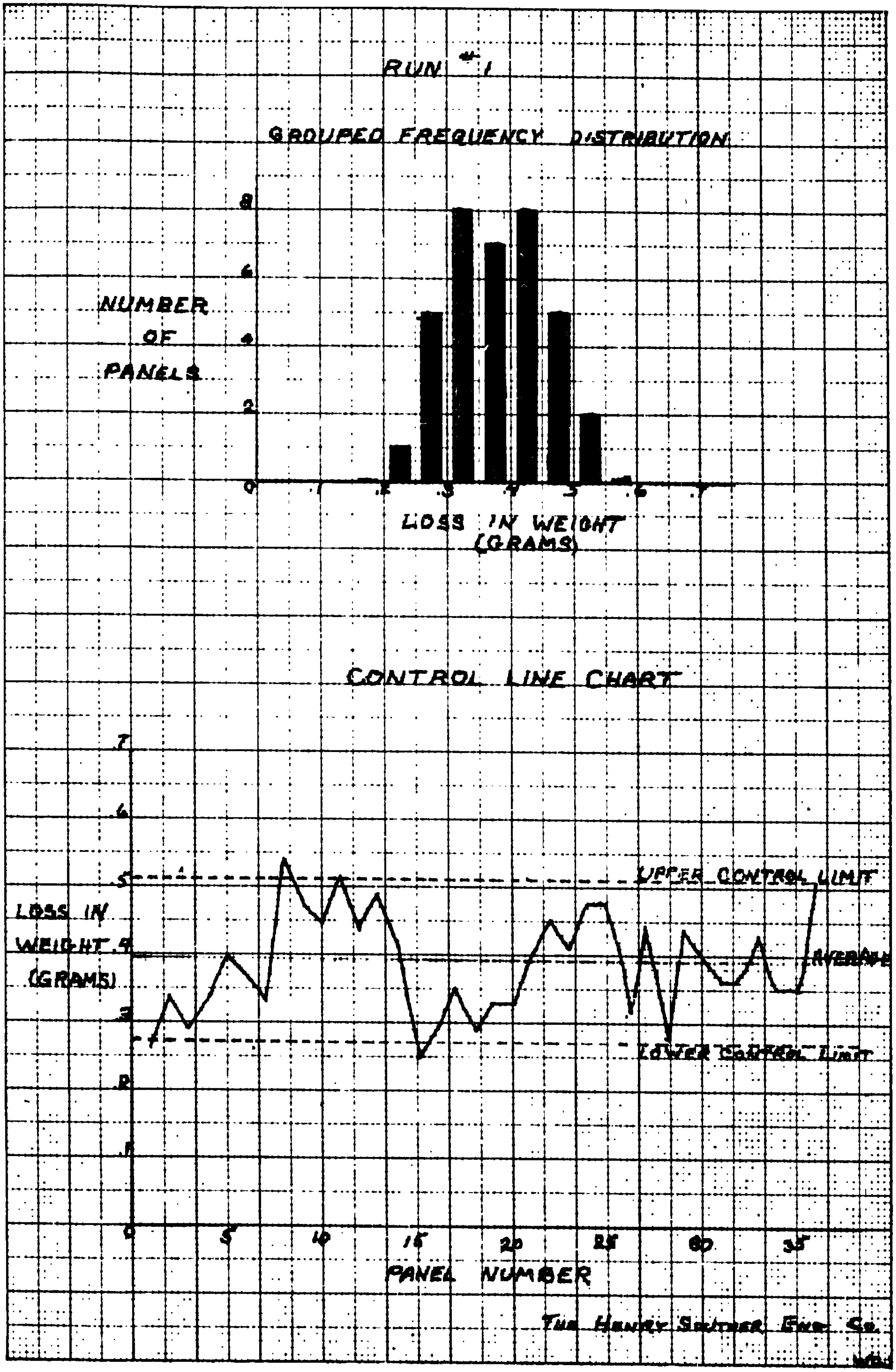
PANEL NUMBER	CUMULATIVE WEIGHT LOSS (grams) 9/21/51 24 hours	9/25/51 48 hours	9/26/51 3 days	9/27/51 4 days	9/28/51 5 days	10/1/51 8 days	NOTES
1	.0463	.1041	.2245	.2432	.2496	.2643	
2	.0186	.1189	.2424	.3082	.3330	.3339	
3	.0363	.0948	.2105	.2527	.2568	.2962	
4	.0266	.1323	.2600	.3148	.3238	.3350	
5	.0328	.1351	.2642	.3436	.3938	.3956	
6	.0606	.1375	.2636	.3336	.3570	.3701	
7	.0750	.1599	.2869	.3183	.3518	.3538	
8	.0791	.1984	.3473	.4290	.5180	.5404	
9	.0605	.1634	.3125	.3971	.4727	.4921	
10	.0397	.1260	.2635	.3249	.3914	.4489	
11	.0957	.1709	.3298	.4282	.5019	.6119	
12	.0701	.1652	.2992	.3890	.4256	.4314	
13	.0452	.1450	.3137	.3918	.4548	.4852	
14	.0468	.1452	.2921	.3537	.4049	.4152	
15	.0550	.1391	.2120	.2302	.2354	.2400	
16	.0650	.1208	.2147	.2458	.2589	.2308	
17	.0418	.1240	[illegible]	.2365	.3112	.3474	
18	.0356	.0988	.2062	.2658	.2788	.2939	
19	.0472	.1137	.2463	.2759	.3193	.3278	
20	.0560	.1256	.2490	.3157	.3477	.3849	
21	.0573	.1474	.2919	.3567	.3880	.3941	
22	.0554	.1244	.2720	.3669	.4390	.4448	
23	.0288	.1519	.2839	.3626	.3998	[illegible]	
24	.0326	.1488	.3152	.3992	.4477	.4716	
25	.0272	.1358	.2413	.3537	.4324	.4727	
26	.0299	.1016	.1947	.2106	.2391	.2461	
27	.0215	.1324	.2674	.3405	.4146	.4470	
28	.0390	.1153	.2248	.2565	.2602	.2583	
29	.0175	.0927	.2598	.3299	.4074	.4313	
30	.0211	.1389	.2784	.3543	.3329	.3981	
31	.0311	.1339	.2723	.3215	.3485	.3582	
32	.0833	.1526	.2516	.3057	.3333	.3659	
33	.0209	.1268	.2551	.3298	.3457	.4217	
34	.0274	.1304	.2629	.3118	.3254	.3488	
35	.0270	.1125	.2474	.2975	.3457	.4217	
36	.0197	.1689	.3232	.3993	.4852	.5020	

APPENDIX B

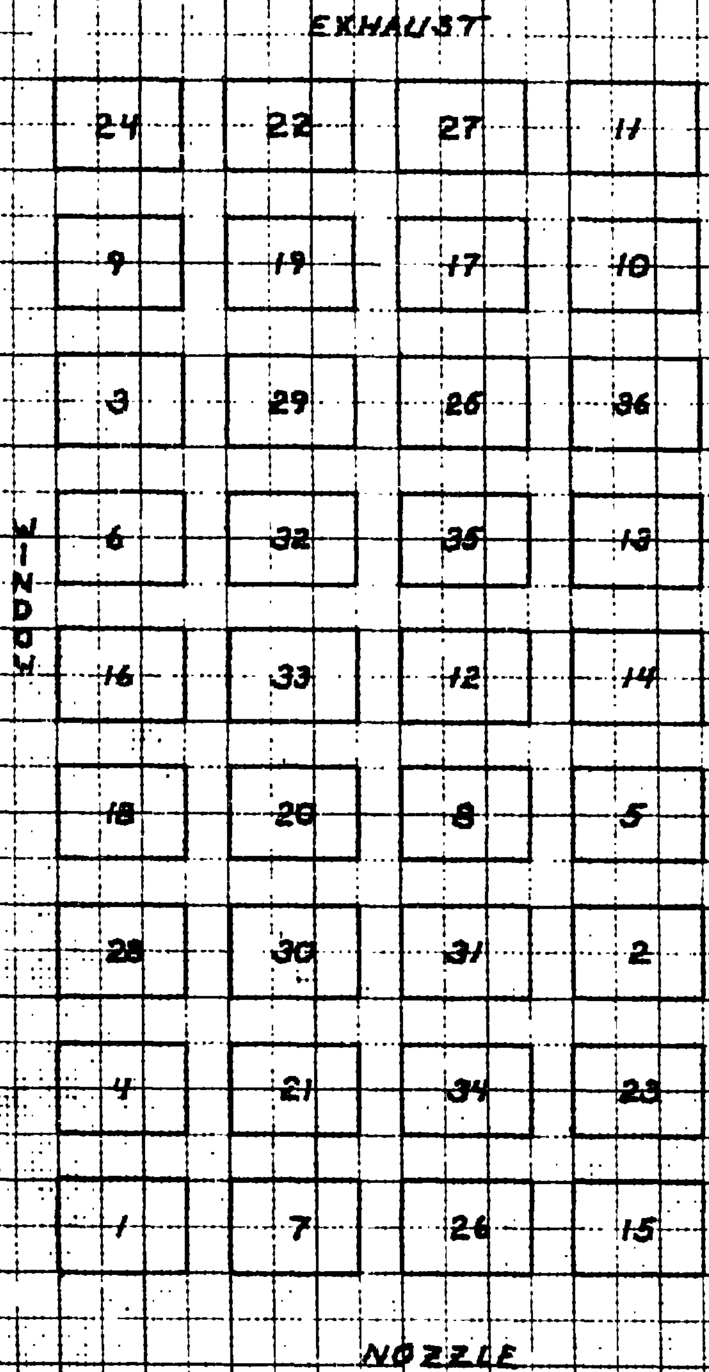


The Henry Sumner Eng. Co.

APPENDIX C



RUN #1
GROUPED FREQUENCY DISTRIBUTION
NUMBER OF PANELS
8
6
4
2
0
.1
.2
.3
.4
.5
.6
.7
LOSS IN WEIGHT (GRAMS)
CONTROL LINE CHART
.7
.6
.5
.4
.3
.2
.1
0
UPPER CONTROL LIMIT
AVERAGE
LOWER CONTROL LIMIT
LOSS IN WEIGHT (GRAMS)
5
10
15
20
25
30
35
PANEL NUMBER
THE HENRY SOUTHER ENG. CO.



PLOT SHOWING RANDOM DISTRIBUTION
OF THE 36 PANELS

The Henry Souther Eng. Co.

TEST NO. 2

Object

The object of this test is to compare the corrosion rate of test specimens at the various locations within the salt spray cabinet.

Summary

Test No. 2 is a repeat of Run #1 and was for the purpose of checking the results obtained in Run #1. The operating conditions and procedures followed were the same as those of Run #1 with the following changes:

1. The panels were observed on the 1st, 2nd, 3rd, 7th and 8th days.
2. The average air pressure was lower than in Run #1.

Discussion

The group frequency distribution for Test No. 2 shows a much greater spread in the range of weight losses and, although the distribution is more irregular than in Run #1, the tendency toward an even distribution around the average value persists.

Due to the larger range of values, the standard deviation and consequently the control limits are larger, and all of the values fall within these limits.

The plot depicting the amount of corrosion (weight loss) with respect to the position in the salt spray cabinet shows approximately the same distribution pattern as was previously obtained.

The chart correlating the amount of corrosion with the day shows a maximum weight loss on the second day as compared with a maximum on the third day, obtained in Run #1.

Conclusion

The results obtained in this test fall into the general pattern of those obtained in Run #1. The same unevenness in the rate of corrosion exists and the greatest weight losses occurred in the same section of the box.

APPENDIX

TEST NUMBER II

COMPARISON OF CORROSION RATES AT VARIOUS TEST LOCATIONS

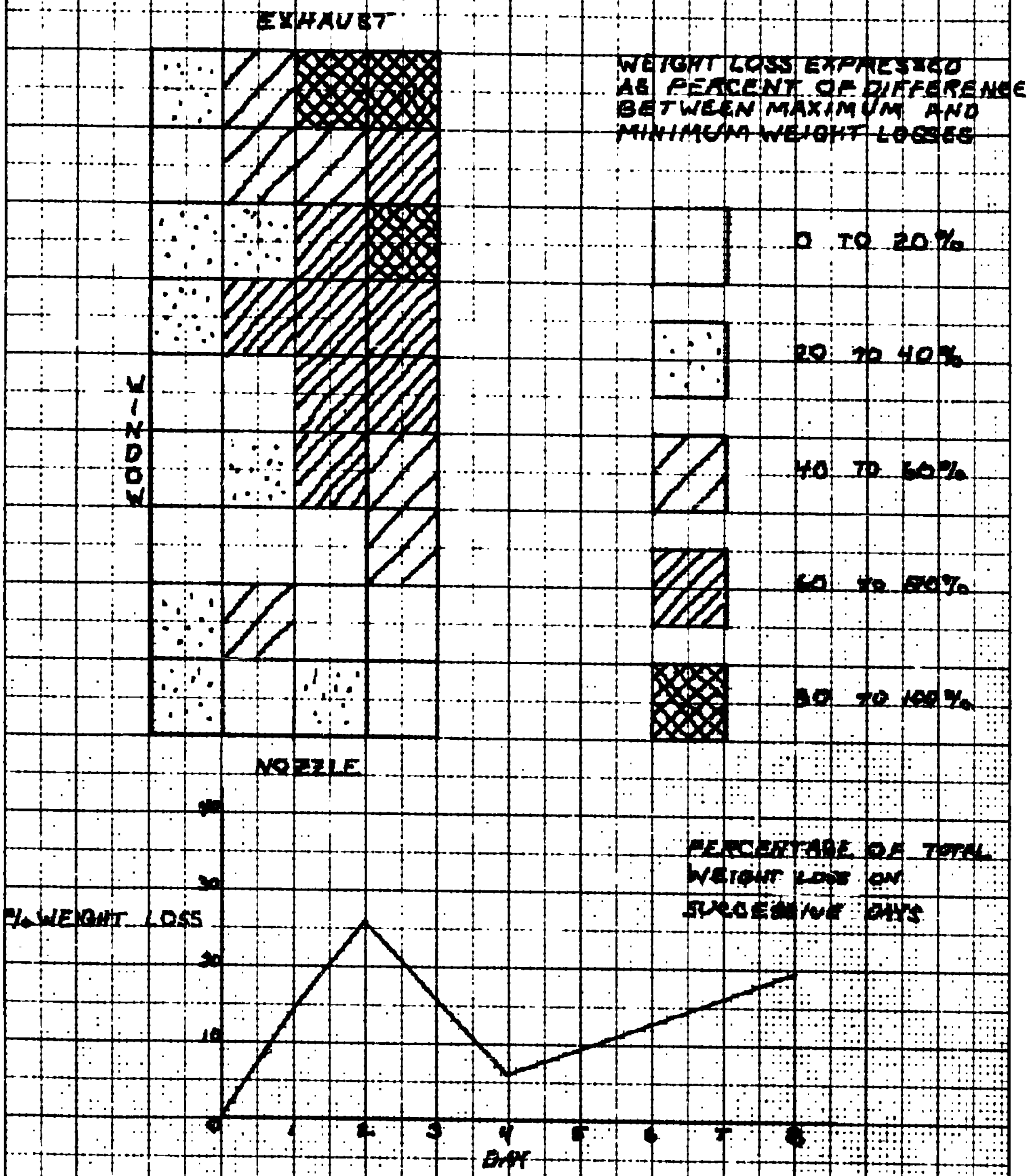
HOURS	10/2/51	10/3/51	10/4/51	10/8/51	10/23/51
Solution Composition.	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O
Dry Bulb Temperature. (°F.)	100°	98°	98°	98°	98°
Wet Bulb Temperature. (°F.)	100°	98°	98°	98°	98°
Relative Humidity.	100%	100%	100%	100%	100%
Particle Size. Av. (microns)	.5	.5	.5	.5	.5
Rate of Settling (mm./sec.)	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
Air Pressure. (lbs./in.^{2})	10	9	9.5	10	14
Air Temperature. (° F.)	95°	95°	95°	95°	95°
Rate of Flow. (ft.^{3}/minute)	.43	.43	.43	.43	.43
pH of Solution.	6.0	6.0	6.0	6.0	6.2
pH of Fog.	6.0	6.0	6.0	6.0	6.2
Rate of Fog Collection. (ml./hour)	1.45	1.57		1.45	1.75
Impurities in Salt Solution. 1. Assay 2. Br and I 3. Heavy metals	—	—	—	—	—
Specific Gravity of Solution.	—	—	—	—	—
Volume of Solution in Reservoir.	—	—	—	—	

CUMULATIVE WEIGHT LOSS

PANEL NUMBER	10/2/51 24 hours	10/3/51 48 hours	10/4/51 3 days	10/8/51 7 days	10/23/51 8 days	NOTES
1	.0533	.1414	.1724	.2091	.2531	
2	.0667	.1500	.1948	.2384	.3114	
3	.0485	.1221	.1620	.1968	.2306	
4	.0656	.1356	.1698	.2018	.2481	
5	.0628	.1462	.2062	.2677	.3391	
6	.0406	.1171	.1459	.1897	.2605	
7	.0541	.1341	.1540	.1760	.2119	
8	.0442	.1206	.2666	.3745	.4642	
9	.0383	.1096	.1205	.1570	.1950	
10	.0544	.1555	.3391	.3977	.4688	
11	.0382	.1518	.3051	.3855	.4823	
12	.0556	.1155	.2719	.3359	.4091	
13	.0310	.1204	.2941	.3721	.4497	
14	.0536	.1355	.2956	.3788	.4689	
15	.0288	.0813	.0888	.0966	.1395	
16	.0300	.1059	.1409	.1596	.1989	
17	.0671	.1619	.2111	.2759	.3246	
18	.0425	.1351	.1650	.1915	.2225	
19	.0160	.0855	.2175	.2898	.3552	
20	.0295	.1206	.1690	.2005	.2432	
21	.0316	.1521	.2598	.3270	.3892	
22	.0547	.1623	.2641	.3399	.3920	
23	.0266	.0701	.1063	.1387	.2008	
24	.0176	.0724	.1512	.2275	.2848	
25	.0679	.1774	.2679	.3555	.4130	
26	.0359	.1208	.1297	.1640	.2779	
27	.0753	.1139	.3529	.4026	.4959	
28	.0550	.0935	.1133	.1219	.1560	
29	.0390	.1243	.1945	.2333	.2711	
30	.0451	.0949	.0997	.1193	.1669	
31	.0152	.0861	.1122	.1640	.2172	
32	.0571	.1361	.2600	.3522	.4098	
33	.0437	.1262	.1437	.1635	.1962	
34	.0370	.0700	.1215	.1557	.2041	
35	.0640	.1273	.2792	.3608	.4455	
36	.0935	.1968	.3684	.4692	.5638	

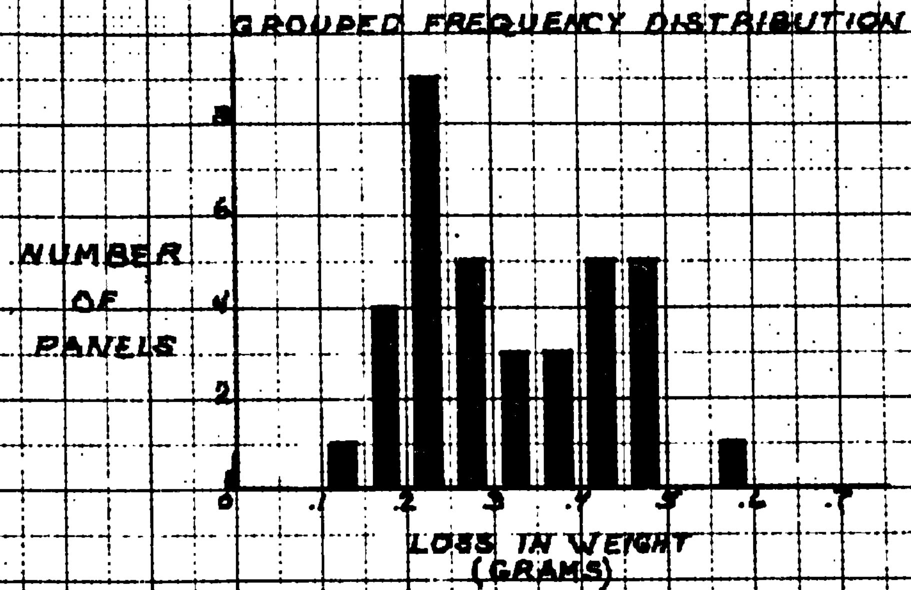
RUN #2

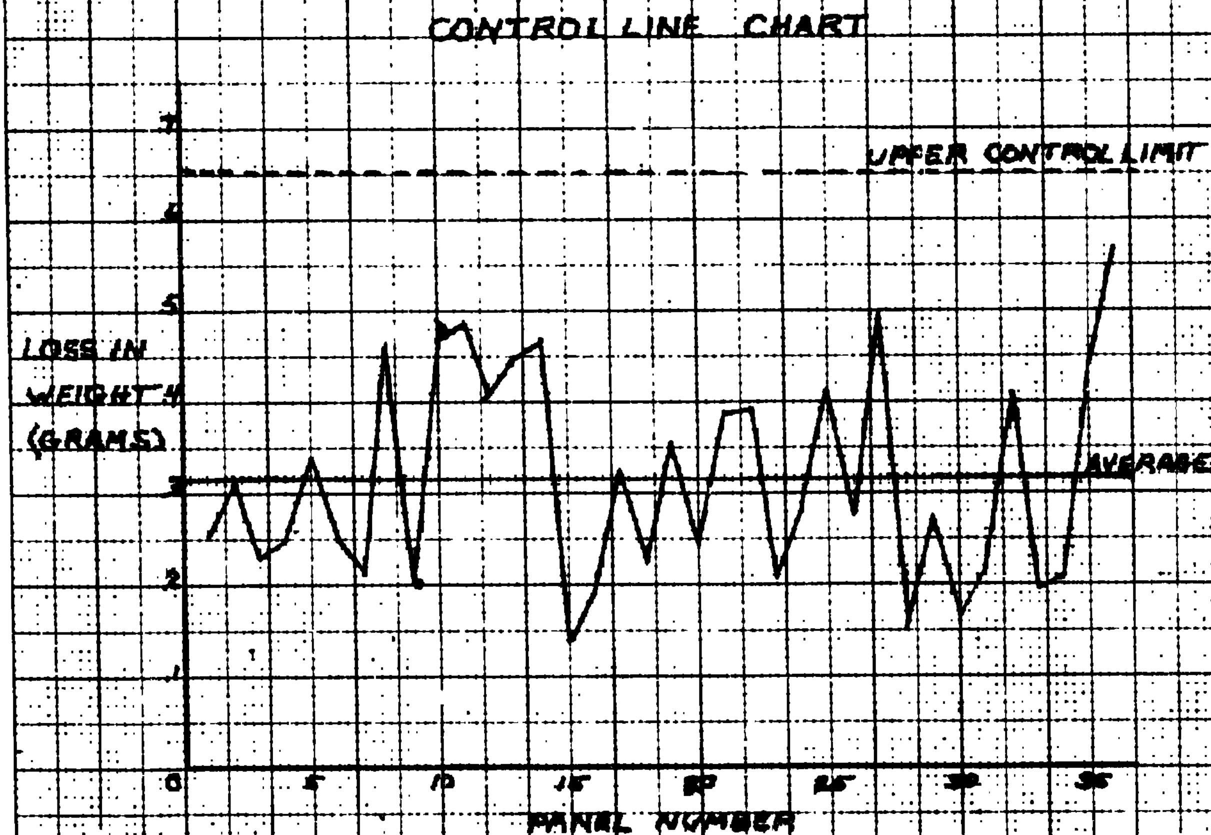
WEIGHT LOSS FOR VARIOUS POSITIONS
IN THE SALT SPRAY CABINET



THE HENRY SOUTHER ENG. CO.

RUN #2





The Henry Souther Eng. Co.

TEST NO. 3

Object

The object of this test is to compare the corrosion rate of test specimens at the various locations within the salt spray cabinet.

Summary

Test No. 3 represents an effort to determine the effect of a lower atomizing nozzle pressure on the rate of corrosion in the salt spray cabinet.

Introduction

The nozzle pressure directly controls the rate at which the solution is atomized and, therefore, should be an important determining factor on the rate of corrosion. Lowering the pressure should make a change in the rate of corrosion and possibly in the pattern of the distribution of the rate of the corrosion within the box.

Procedure

The procedure was the same as previously obtained except that the nozzle pressure was lowered to a value between 4 and 6.5 psi. The panels were observed on the 1st, 4th, 5th, 6th, 7th and 8th days.

Discussion

The grouped frequency distribution for Run #3 shows a closer grouping of values than was obtained in Run #2 and differs from Runs #1 and #2 in that it shows a definite skewness that had not been observed before.

The control line chart shows a smaller overall variation in values and an average that is lower than those previously obtained.

The weight loss distribution presents an entirely different pattern than those obtained in Runs #1 and #2. The areas of maximum corrosion do not seem to group themselves in any particular section of the box although the general area of the maximum corrosion rate is the middle third of the test area. The maximum weight loss occurred on the first day.

Conclusions

Lowering the air pressure has a definite effect on the corrosion rate, and its correlation with the fog distribution pattern should be investigated.

APPENDIX

TEST NUMBER III **VARIABLE: RATE OF FLOW**

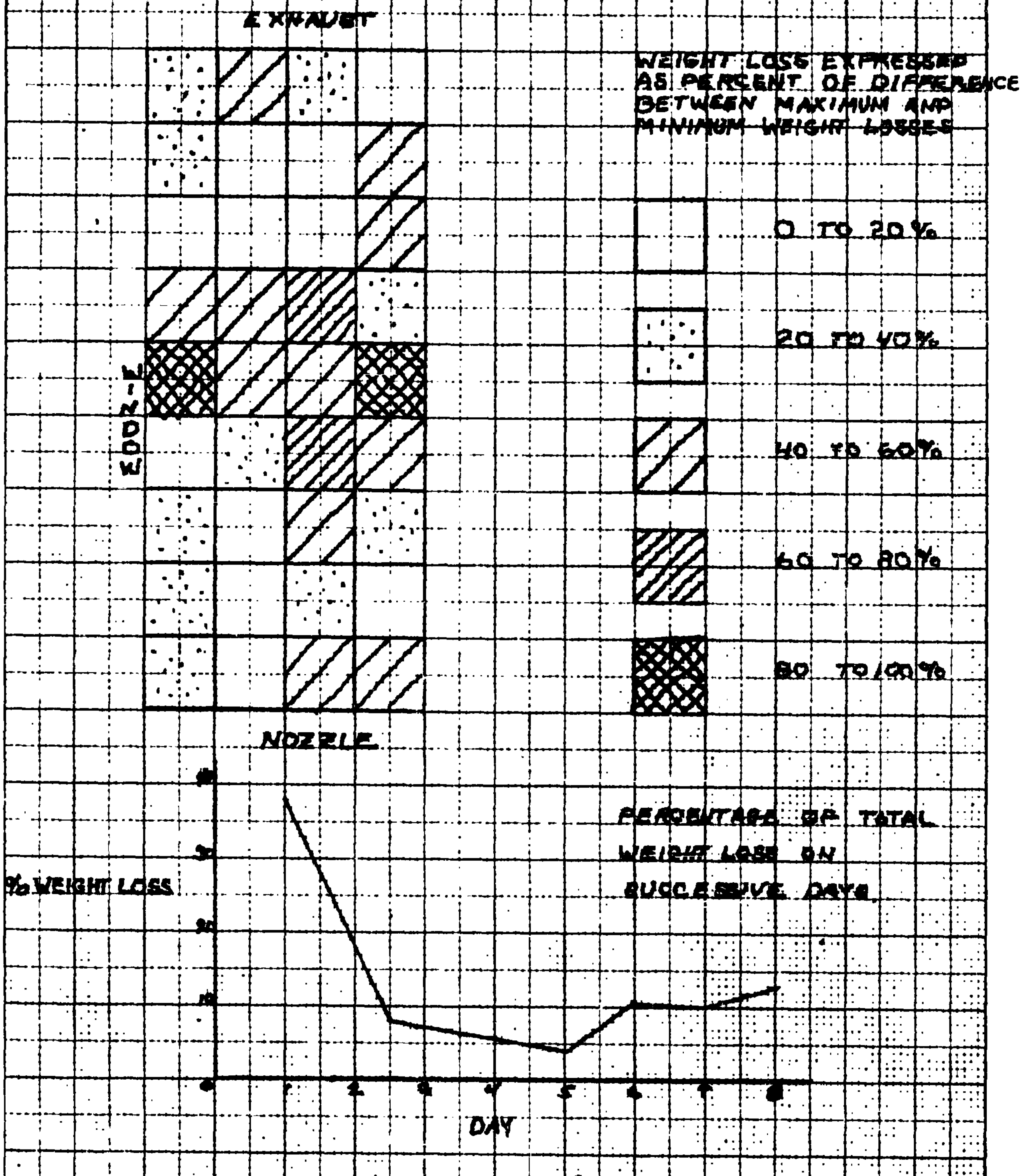
HOURS

	10/12/51	10/16/51	10/17/51	10/18/51	10/22/51
Solution Composition.	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O
Dry bulb Temperature. (° F.)	99°	95°	98°	97°	99°
Wet bulb Temperature. (° F.)	98°	97°	98°	97°	97°
Relative Humidity.	100%	100	100%	100%	100%
Particle Size. (microns) Av.	.06	.05	.05	.05	.05
Rate of Settling. (mm./second)	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
Air Pressure. (lbs./in.^{2})	6.5	5	4	5.6	6.2
Air Temperature. (° F.)	96°	95°	95°	96°	95°
Rate of Flow. (ft.^{3}/minute)	.36	.42	.36	.36	.36
pH of Solution.	6.4	6.2	6.2	6.2	6.2
pH of Fog.	6.4	6.2	6.2	6.2	6.2
Rate of Fog Collection. (ml./hour)	1.33	.92	1.32	1.46	1.38
Impurities in Salt Solution. 1. Assay 2. Br and I 3. Heavy Metals	—	—	—	—	—
Specific Gravity of Solution.	—	—	—	—	—
Volume of Solution					

COMPARISON OF CORROSION RATES AT VARIOUS TEST LOCATIONS

PANEL NUMBER	**CUMULATIVE WEIGHT LOSSES** (grams)					**NOTES**
	10/12/51 24 hours	10/16/51 4 days	10/16/51 5 days	10/17/51 6 days	10/18/51 7 days	10/23/51 8 days
1	.0692	.1539	.1520	.1509	.1775	.1538
2	.0905	.1125	.1204	.1274	.1597	.1558
3	.0709	.0965	.1005	.1091	.1191	.1516
4	.0723	.1314	.1357	.1373	.1614	.1735
5	.0985	.1641	.1621	.1904	.2141	.2624
6	.0904	.1568	.1763	.2092	.2423	.2702
7	.0742	.1027	.1072	.1146	.1230	.1589
8	.0942	.1305	.1397	.2242	.2473	.2638
9	.0798	.1141	.1307	.1408	.1602	.1926
10	.1222	.1551	.1494	.1872	.1922	.2350
11	.0821	.0914	.1031	.1120	.1402	.1688
12	.0819	.1598	.1626	.1919	.2158	.2364
13	.0913	.1843	.2045	.2459	.2307	.3123
14	.0935	.1930	.2052	.2341	.2590	.3696
15	.0455	.1027	.1260	.1551	.1977	.2186
16	.0831	.1848	.2179	.2601	.3423	.3467
17	.0835	.1005	.1053	.1118	.1271	.1409
18	.0706	.1239	.1255	.1317	.1412	.1651
19	.0302	.1032	.1080	.1197	.1290	.1451
20	.0937	.1505	.1597	.1675	.1752	.1939
21	.0836	.1060	.1137	.1200	.1415	.1522
22	.0611	.1197	.1429	.1752	.2026	.2310
23	.0533	.0624	.0794	.1122	.1295	.1504
24	.0663	.1031	.1171	.1297	.1475	.1761
25	.0544	.0958	.0990	.1123	.1219	.1523
26	.0557	.1135	.1395	.1680	.1926	.2212
27	.0763	.0902	.1186	.1445	.1519	.1957
28	.0716	.1569	.1627	.1743	.1917	.2018
29	.0638	.1233	.1306	.1421	.1409	.1665
30	.0733	.1355	.1049	.1045	.1172	.1241
31	.0354	.1552	.1569	.1460	.1956	.2292
32	.0376	.1139	.1937	.1933	.2140	.2336
33	.0862	.1595	.1615	.1769	.1920	.2136
34	.0303	.1143	.1515	.1431	.1685	.1967
35	.0320	.1770	.1798	.2174	.2399	.2746
36	.0663	.1370	.1476	.1777	.2140	.2601

RUN #3
WEIGHT LOSS FOR VARIOUS POSITIONS IN THE SALT SPRAY CABINET

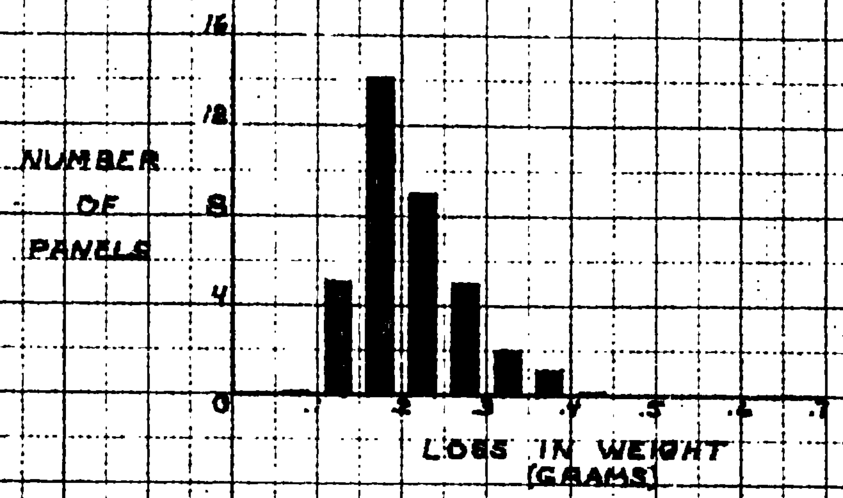


The Henry Souther Eng. Co.

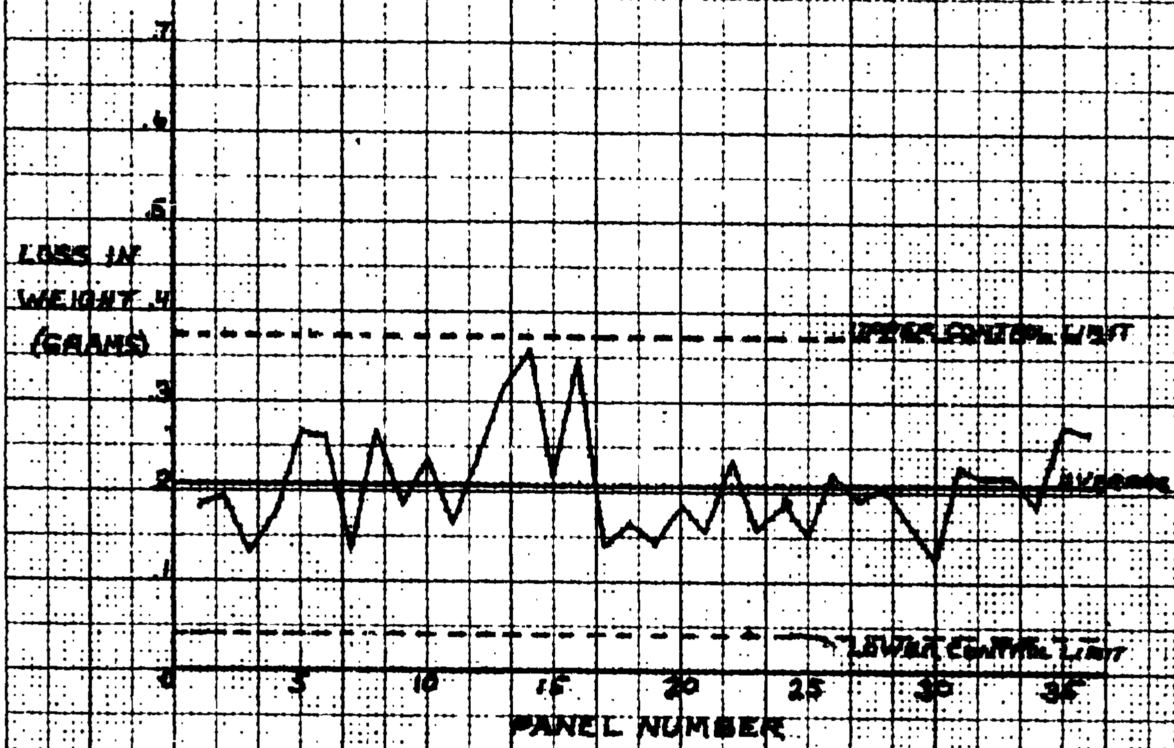
(JEL)

RUN # 3

GROUPED FREQUENCY DISTRIBUTION



CONTROL LINE CHART



The Henry Souther Eng. Co.

TEST NO. 4

FOG DENSITY OBSERVATIONS

Object

The object of this test is to determine the uniformity of fog densities at the various locations within the salt spray cabinet, the relationship between these fog densities and the rates of corrosion of the specimens, and to attempt an improvement in fog distribution.

Summary

Tests have been conducted to determine the rate of fog collection at the various locations within the salt spray cabinet and compared with the corrosion rates of the steel panels used in Tests Nos. 1, 2 and 3, and variations made in positions of the nozzle to attempt an improvement in fog distribution.

Introduction

The purpose of this phase of the investigation is to determine the relationship of the fog densities at various locations within the salt spray cabinet to the weight losses of the steel panels used in Tests Nos. 1, 2 and 3.

Procedure

Run 1 - Thirty-six, 600-milliliter beakers, which had previously been cleaned and dried, and weighed, were placed on a large wooden paraffined rack in the salt spray cabinet in the positions previously occupied by the steel specimens. The atomizing nozzle was directed away from the panels and against an end wall of the box so that any spray falling into the beakers had been reflected from the wall. This was to provide a more even distribution of the fog in the cabinet and to duplicate the conditions of Test No. 1. Tap water was used to generate the fog, and the temperature was maintained at 95°F. The air pressure was the same as that in Test No. 1. At the end of 23.4 hours, the beakers were removed from the cabinet, dried on the outside and weighed to the nearest tenth of a gram. From the data compiled, the percentages of fog collections were computed and appear in Appendix A, while plots of the densities appear in Appendix E.

Run 2 - A repeat run on the above was performed, and these results also appear in Appendixes A and B.

Run 3 - In an attempt to provide a more even distribution of fog, the beakers were placed in the cabinet as before and two nozzles, arranged at equal distances from either end of the cabinet, directed the sprays at the end walls. The temperature was maintained at 95°F, and the pressure the same as before. At the end of 23.4 hours, the beakers were removed and weighed as before. From the data compiled, the percentages of fog collections were computed and appear in Appendix A.

Run 4 - A repeat of Run 3 was performed, and these results also appear in Appendixes A and B.

Run 5 - Again attempting to obtain a more even distribution of fog, the rack in the salt spray cabinet was raised 24 inches from the bottom of the cabinet and the beakers placed as before. A single nozzle was placed in the center pointing vertically downward, with the spray directed at a low cone-shaped glass piece 14 inches in diameter for the purpose of directing the spray up and around the rack above the nozzle. At the end of six hours, the beakers were removed and weighed as before. The results appear in Appendixes A and B.

Run 6 - For this test, forty 600-milliliter beakers were used. The wooden rack was removed from the cabinet and the beakers were placed in two groups of twenty (four rows of five beakers) at either end of the box. The nozzle was set in the center of the box with the spray directed vertically downward into a 14-inch circular section battery jar. At the end of six hours, the beakers were removed and dried, and weighed, as before. The results of this run appear in Appendixes A and B.

Run 7 - This run was a repeat of Run 6, except that the cover was raised one inch. The results of this run appear in Appendixes A and B.

Run 8 - This run was performed in the same manner as Run 1, except for 40 hours duration, with all the conditions similar with the exception of the air pressure which was lowered to 5 lbs. per square inch. The results of this run appear in Appendixes A and B.

Run 9 - This run was performed in a commercial salt spray cabinet manufactured by the Industrial Filter and Pump Manufacturing Co. (Serial S-1540, Type CA 1, 37-1/2 inches long, 24-1/2 inches wide and 48 inches from the bottom of the box to the apex). Thirty-five 600-milliliter beakers were placed on a wooden rack in the box at the level of the trough, and the box run for eight hours. The beakers were then removed from the box and weighed. The results appear in Appendixes A and B.

Run 10 - This was a repeat on Run 9, with the exception of the number of beakers used which was forty. The run was for a period of 48 hours at which time the beakers were removed and weighed. The results appear in Appendixes A and B.

Discussion and Conclusions

Examination of the data and charts covering these runs shows that only slight gains are made in the uniformity of distribution of fog by changing nozzle positions. The fog distribution is apparently closely tied up with the position of the nozzle in relation to the outlet rather than the nozzle alone.

Good correlation of the test is apparent by the distribution of fog noted in Runs 1 and 2. Comparison of these results with the fog distribution at lower pressure, as shown in Run 8, shows that the rate of travel of the fog across the cabinet bears some relation with the fog distribution.

Comparison of the corrosion rates of Tests Nos. 1, 2 and 3 with the fog densities of Runs 1, 2 and 8 shows that the corrosion rate varies inversely with the fog density. A more important relationship will be developed when these results are compared with runs using salt spray.

APPENDIX A

DATA ON TEST # 4, RUN I

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	32.0	1.37	95.9
2	30.9	1.32	92.7
3	19.9	.850	53.7
4	24.1	1.03	68.3
5	21.4	.976	59.3
6	21.7	.990	60.2
7	30.3	1.32	91.9
8	16.6	.710	42.3
9	16.4	.700	41.5
10	10.8	.460	22.0
11	10.5	.450	21.1
12	14.5	.620	35.0
13	14.2	.610	34.1
14	15.9	.680	39.8
15	31.3	1.37	97.0
16	20.1	.860	54.5
17	9.10	.390	16.3
18	19.6	.840	52.8
19	11.4	.490	24.4
20	15.2	.650	37.4
21	19.8	.850	54.5
22	10.6	.450	21.5
23	33.1	1.42	100.0
24	13.0	.560	30.1
25	9.90	.420	18.7
26	28.6	1.23	84.6
27	8.70	.370	14.8
28	19.9	.850	53.7
29	4.40	.190	0
30	15.9	.680	39.8
31	17.1	.730	43.9
32	12.5	.540	28.5
33	14.0	.600	33.3
34	20.2	.860	55.3
35	13.2	.570	30.9
36	11.5	.510	26.0

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.) Av.	2×10^{-4}
Dry Bulb Temp.(° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(° F.)	99°	Air Temperature (°F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN II

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	21.9	1.00	100.0
2	19.4	.880	86.1
3	19.7	.900	87.8
4	21.6	.980	98.4
5	12.2	.550	40.1
6	20.4	.930	91.5
7	21.2	.960	96.1
8	11.2	.510	40.6
9	16.6	.750	70.6
10	8.10	.370	23.2
11	8.90	.400	27.8
12	9.30	.420	30.0
13	7.70	.350	21.0
14	8.80	.400	27.2
15	20.0	.910	89.5
16	19.5	.890	86.7
17	8.20	.370	23.9
18	19.3	.880	85.4
19	13.6	.620	53.7
20	15.9	.720	65.9
21	18.3	.830	79.3
22	10.8	.490	37.8
23	18.6	.850	81.7
24	13.6	.620	53.7
25	8.30	.380	24.4
26	21.6	.930	97.6
27	8.70	.400	26.8
28	20.4	.930	91.5
29	3.90	.180	0
30	17.9	.810	76.8
31	12.3	.560	46.3
32	11.1	.500	39.0
33	13.2	.600	51.2
34	15.3	.700	63.4
35	8.70	.400	26.8
36	7.60	.350	20.7

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.) Av.	2×10^{-4}
Dry Bulb Temp. (° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp. (° F.)	99°	Rate of Flow (ft.^{3}/min.)	.15
Relative Humidity	100%	Air Temperature (°F.)	95°
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN III

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	8.30	.354	62.7
2	7.80	.334	58.7
3	.700	.030	2.40
4	5.30	.226	38.9
5	5.80	.248	42.9
6	1.20	.051	6.35
7	6.10	.261	45.2
8	1.60	.068	9.50
9	.400	.017	0
10	2.40	.102	15.9
11	1.60	.068	9.50
12	1.30	.056	7.10
13	3.20	.137	22.2
14	4.00	.171	28.6
15	13.0	.556	100.0
16	.800	.034	3.20
17	1.20	.051	6.30
18	1.30	.056	7.10
19	1.20	.051	6.30
20	.900	.038	4.00
21	4.40	.188	31.7
22	1.10	.047	5.60
23	9.60	.410	73.0
24	.900	.038	4.00
25	1.60	.068	9.50
26	5.50	.235	40.5
27	1.10	.047	5.60
28	3.10	.132	21.4
29	.800	.034	3.20
30	1.50	.064	8.70
31	2.70	.115	18.3
32	.500	.021	.900
33	.800	.034	3.20
34	4.40	.188	31.7
35	1.00	.043	4.80
36	2.60	.111	17.5

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	* Rate of Settling (mm./sec.)	2×10^{-4}
Dry Bulb Temp.(° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(° F.)	99°	Air Temperature (° F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN IV

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	7.50	1.25	100.0
2	4.20	.700	53.5
3	2.30	.383	40.8
4	[illegible].40	.900	70.4
5	3.20	.533	39.4
6	2.30	.383	26.7
7	4.20	.700	53.5
8	1.50	.250	15.4
9	2.40	.400	28.1
10	1.60	.267	16.9
11	2.20	.369	25.3
12	2.20	.368	25.3
13	2.40	.400	28.1
14	1.50	.250	15.4
15	3.50	.583	43.8
16	2.30	.383	26.7
17	2.20	.368	25.3
18	2.70	.450	32.3
19	1.80	.300	19.7
20	1.50	.250	15.4
21	2.70	.450	32.3
22	2.40	.400	28.1
23	3.90	.650	49.2
24	3.30	.550	40.8
25	1.40	.233	14.0
26	1.40	.233	14.0
27	.700	.117	4.20
28	3.10	.517	38.0
29	1.60	.267	16.9
30	1.40	.233	14.0
31	1.40	.233	14.0
32	.600	.100	2.80
33	1.20	.200	11.3
34	1.60	.267	16.9
35	2.00	.333	22.5
36	.400	.067	0

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.)	2×10^{-4}
Dry Bulb Temp.(° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(° F.)	99°	Air Temperature (° F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN V

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	4.30	.716	9.37
2	4.70	.783	15.6
3			
4	4.50	.752	12.5
5	3.70	.617	0
6	5.30	.885	25.0
7	5.30	.885	25.0
8			
9	5.10	.850	21.9
10	4.10	.684	6.25
11	6.20	1.03	39.1
12	6.10	1.02	37.5
13	5.80	.968	32.8
14	6.00	1.00	36.0
15	6.00	1.00	36.0
16	6.80	1.14	48.4
17	7.10	1.19	53.1
18	6.90	1.15	50.0
19	7.80	1.30	64.1
20	7.10	1.19	53.1
21	10.1	1.68	100.0
22	9.90	1.65	97.0
23	8.80	1.47	79.8
24	7.40	1.23	57.9
25	7.90	1.32	65.6
26	9.50	1.58	90.6
27	8.70	1.45	78.1
28	8.00	1.33	68.1
29	6.40	1.07	42.1
30	7.20	1.20	54.8
31	8.30	1.38	71.9
32	9.20	1.54	86.0
33	7.40	1.23	57.9
34	6.80	1.14	48.4
35	6.40	1.07	42.3
36	6.90	1.15	50.0
37	6.80	1.14	48.4
38	6.90	1.15	50.0
39	6.40	1.07	42.3
40	5.30	.885	25.0

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.)	2×10^{-4}
Dry Bulb Temp.(°F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(° F.)	99°	Air Temperature (° F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN VI

Number of Beaker	Mls. Collected	Mls./hr.	%
1	1.80	.300	6.50
2	2.30	.384	9.75
3	1.80	.300	6.50
4	.800	.133	0
5	.800	.133	0
6	2.60	.434	11.7
7	2.60	.434	11.7
8	1.60	.266	5.19
9	1.80	.300	6.50
10	1.00	.167	1.30
11	3.90	.650	20.1
12	3.40	.566	16.9
13	2.50	.417	11.1
14	2.30	.384	9.74
15	1.00	.167	1.30
16	3.80	.623	19.5
17	4.30	.716	22.7
18	2.30	.384	9.74
19	3.50	.583	17.5
20	2.80	.467	13.0
21	8.30	1.38	48.7
22	9.20	1.54	54.6
23	8.20	1.37	48.1
24	6.30	1.50	35.7
25	4.60	.767	24.7
26	7.30	1.22	42.3
27	8.00	1.34	46.8
28	8.00	1.34	46.8
29	5.70	.950	35.0
30	7.20	1.20	41.5
32	6.80	1.14	39.0
33	7.00	1.17	40.5
34	11.3	1.38	58.3
35	7.10	1.18	40.9
36	16.2	2.70	100.0
37	6.10	1.02	34.4
38	6.40	1.07	36.4
39	6.10	1.02	34.4
40	4.90	.818	26.6

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.)	2×10^{-2}
Dry Bulb Temp.(° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(°F.)	99°	Air Temperature (° F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN VII

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	25.7	1.07	100.0
2	17.6	.734	52.4
3	10.5	.438	10.6
4	10.9	.454	12.9
5	14.6	.608	34.7
6	10.7	.446	11.8
7			
8	11.8	.492	18.2
9	9.30	.388	3.53
10	12.5	.520	22.4
11	13.8	.575	30.0
12	11.2	.467	14.7
13	12.6	.525	23.0
14	12.6	.525	23.0
15	23.5	.980	87.0
16	10.4	.434	10.0
17	10.9	.454	12.9
18	11.9	.495	18.8
19	9.80	.408	6.47
20	9.70	.404	5.89
21	22.1	.921	78.9
22	8.70	.362	0
23	20.5	.854	69.4
24	10.2	.426	8.84
25	9.90	.413	7.05
26	15.6	.650	40.6
27	12.0	.500	19.4
28	14.9	.621	35.7
29	9.30	.388	3.53
30	9.30	.388	3.53
31	13.0	.541	25.2
32	8.80	.367	.60
33	8.90	.371	1.13
34	14.7	.612	35.4
35	10.3	.429	9.40
36	12.1	.504	20.0

CONDITIONS OF TEST

Solution Composition	Dist. H_2O	Rate of Settling (mm./sec.)	2×10^{-4}
Dry Bulb Temp.(° F.)	99°	Air Pressure (lbs./in.^{2})	15
Wet Bulb Temp.(° F.)	99°	Air Temperature (° F.)	95°
Relative Humidity	100%	Rate of Flow (ft.^{3}/min.)	.15
Particle Size (microns)	.3	pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN VIII

Number of Beaker	Mls. Collected	Mls./ hr.	%
1	1.40	.035	12.5
2	1.00	.025	6.25
3	1.20	.030	9.38
4	1.90	.048	20.2
5	.800	.020	3.13
6	.600	.015	0
7	1.30	.032	10.9
8	1.70	.042	17.2
9	.300	.020	3.13
10	1.20	.030	9.38
11	1.40	.035	12.5
12	2.00	.050	21.9
13	1.50	.038	14.1
14	1.20	.030	9.38
15	1.70	.042	17.2
16	2.20	.055	25.0
17	2.10	.052	23.4
18	1.00	.025	6.25
19	1.90	.048	20.2
20	2.80	.070	34.4
21	2.90	.0[illegible]2	35.9
22	1.60	.040	15.6
23	2.30	.058	26.6
24	3.40	.085	43.8
25	3.50	.087	45.4
26	2.30	.058	26.6
27	3.00	.075	37.5
28	5.00	.125	68.8
29	2.50	.062	29.7
30	2.60	.065	31.2
31	3.90	.097	51.6
32	6.70	.167	85.2
33	2.50	.062	29.7
34	3.20	.080	40.6
35	5.40	1.35	75.0
36	7.00	.175	100.0

CONDITIONS OF TEST

Solution Composition	Dist. H_2O
Dry Bulb Temp.($^{\circ}$ F.)	99°
Wet Bulb Temp.($^{\circ}$ F.)	99°
Relative Humidity	100%
Particle Size	.4

Rate of Settling (mm./sec.)	2×10^{-4}
Air Pressure (lbs./in.^{2})	5
Air Temperature ($^{\circ}$ F.)	99°
Rate of Flow (ft.^{3}/min.)	.55
pH of Solution and Fog	6.0

DATA ON TEST # 4, RUN IX

Number of Beaker	Mls. Collected	Mls. / hr.	%
1	16.1	2.0	83.8
2	14.6	1.8	72.0
3	14.0	1.8	72.0
4	12.6	1.6	57.3
5	10.0	1.3	38.2
6	1[illegible].8	2.0	81.0
7	12.7	1.6	57.3
8	11.9	1.5	52.2
9	10.7	1.3	43.4
10	10.4	1.3	41.2
11	18.1	2.3	97.8
12	10.1	1.3	39.0
13	9.7	1.2	36.0
14	8.8	1.1	29.4
15	9.1	1.1	31.6
16	18.4	2.3	100.0
17	9.1	1.1	31.6
18	8.6	1.1	27.9
19	10.4	1.3	41.2
20	9.0	1.1	30.9
21	1[illegible].5	2.2	93.5
22	8.0	1.0	23.5
23	6.7	.80	14.0
24	5.7	.70	6.60
25	8.2	1.0	2[illegible].0
26	16.7	2.1	87.5
27	7.3	.90	19.4
28	6.7	.80	14.0
29	4.3	.60	0
30	5.3	.70	3.7
31	15.2	1.9	76.5
32	7.0	.90	16.2
33	5.8	.70	8.1
34	6.2	.80	10.3
35	5.4	.70	4.4

CONDITIONS OF TEST

Solution composition	20% NaCl
Relative Humidity	100%
Specific Gravity of Solution	1.150
Particle Size (microns)	.5
Rate of Flow ($ft.^3$/min.)	.46
Rate of Settling (mm./sec.)	3×10^{-5}
Air Pressure (lbs./$in.^2$)	14
Air Temperature ($^\circ$ F.)	95°
pH of Solution	7.2
pH of Fog	7.2

[illegible] 4, R[illegible] X

[illegible]umber of Beaker	[illegible]ls. Collected	[illegible]ls./hr.	[illegible]
1	[illegible].00	.135	70.8
2	9.10	.133	68.2
3	[illegible].00	.1[illegible]7	73.1
4	[illegible].30	.193	[illegible]0.5
5	[illegible].50	.[illegible]3	[illegible]5.6
6	[illegible].20	.183	68.2
7	[illegible].70	.203	[illegible]0.1
8	1[illegible].1	.211	100.0
9	[illegible]. 0	.1[illegible]1	41.6
10	.40	.154	34.2
11	[illegible].00	.146	24.4
12	7.50	.153	31.7
13	7.70	.161	41.5
14	8.40	.175	[illegible]8.8
1[illegible]	8.40	.175	[illegible]8.8
16	9.20	.192	[illegible]8.0
17	6.00	.125	0
18	6.40	.13[illegible]	[illegible].71
19	6.70	.139	17.1
20	6.[illegible]0	.142	19.4
21	6.[illegible]0	.1[illegible]	21.9
22	7.00	.1[illegible]	4[illegible].3
23	.60	.158	[illegible]0
24	[illegible].20	.[illegible]1	[illegible]8.0
25	6. 0	.139	1[illegible].0
26	6.30	.13[illegible]	[illegible].32
27	6. 0	.139	1[illegible].0
28	[illegible].00	.145	24.4
29	.10	.148	2[illegible].9
30	[illegible].50	.152	31.7
31	[illegible].10	.169	51.2
32	9.10	.1[illegible]	[illegible].8
33	7.30	.1[illegible]2	31.7
34	6.80	.141	19.4
35	7.80	.162	43.9
36	7.10	.148	26.9
37	8.20	.1 1	53.6
38	8.20	.171	53.6
39	8.70	.181	65.9
40	8.60	.179	63.5

[illegible] T

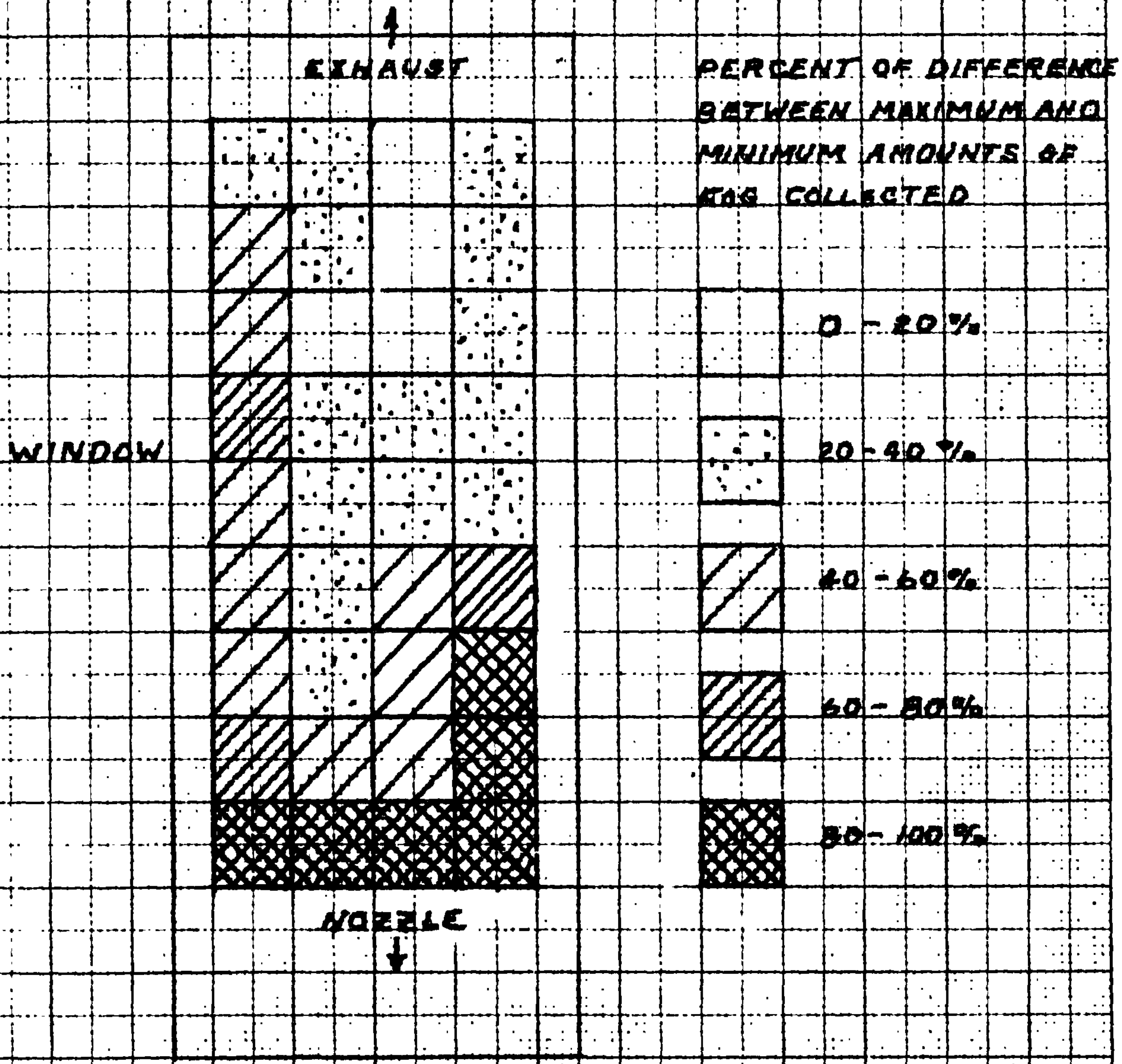
Solution Composition	20 [illegible] NaCl	Rate of Settling (mm./sec.)	3×10^{-5}
Relative Humidity	100	Air Pressure (lbs./in.^{2})	14
Specific Gravity of Solution	1.150	Air Temperature ($^\circ$ F.)	95°
Particle Size (microns)	.5	pH of Solution	7.2
Rate of Flow (ft.^{3}/min.)	.46	pH of Fog	7.2

APPENDIX B

TEST #4

RUN 1

FOG DISTRIBUTION UNDER CONDITIONS OF TESTS #1 + 2



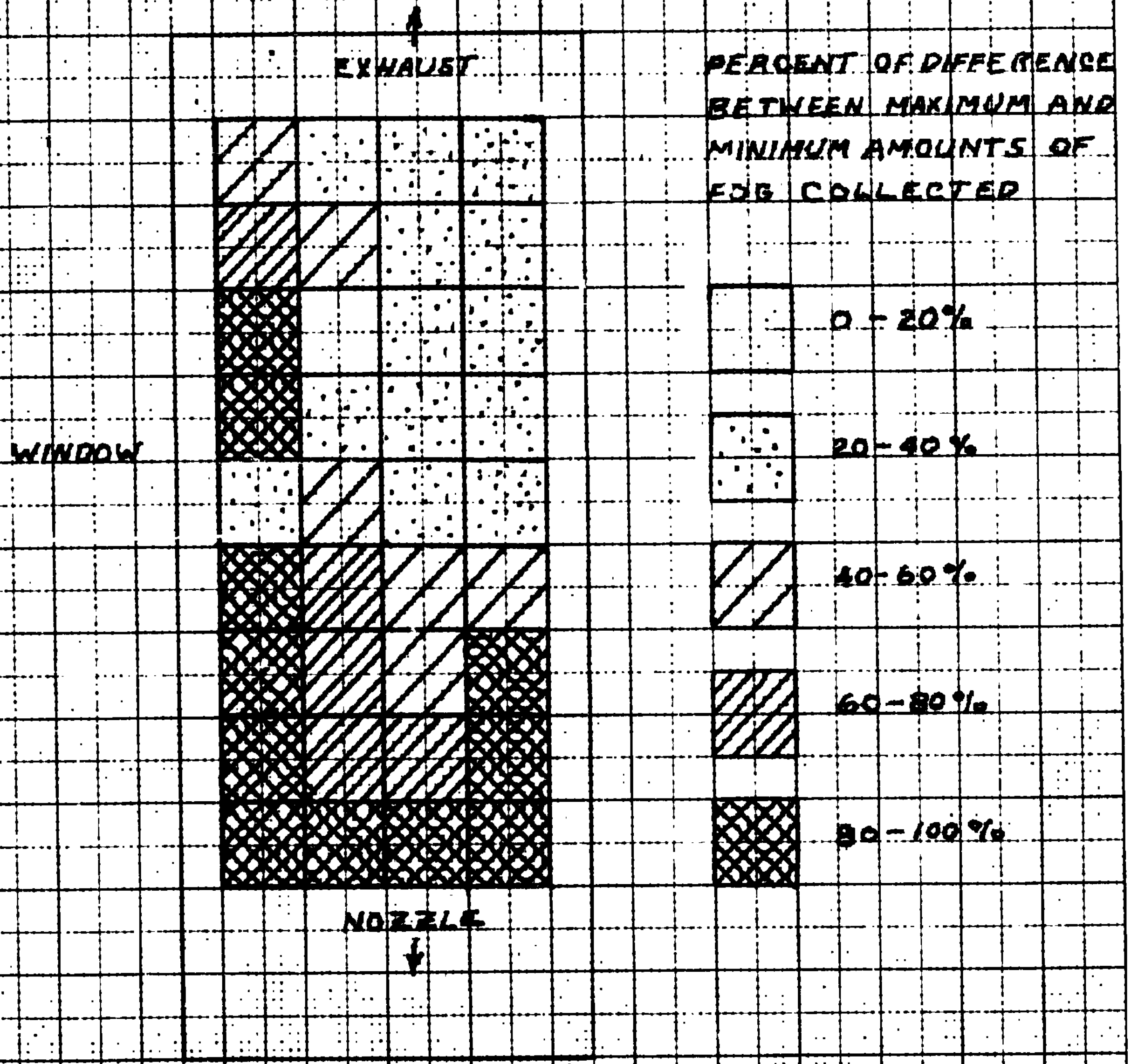
The Henry Souther Eng Co.

WCJ

TEST # 4

RUN 2

REPEAT OF RUN 1



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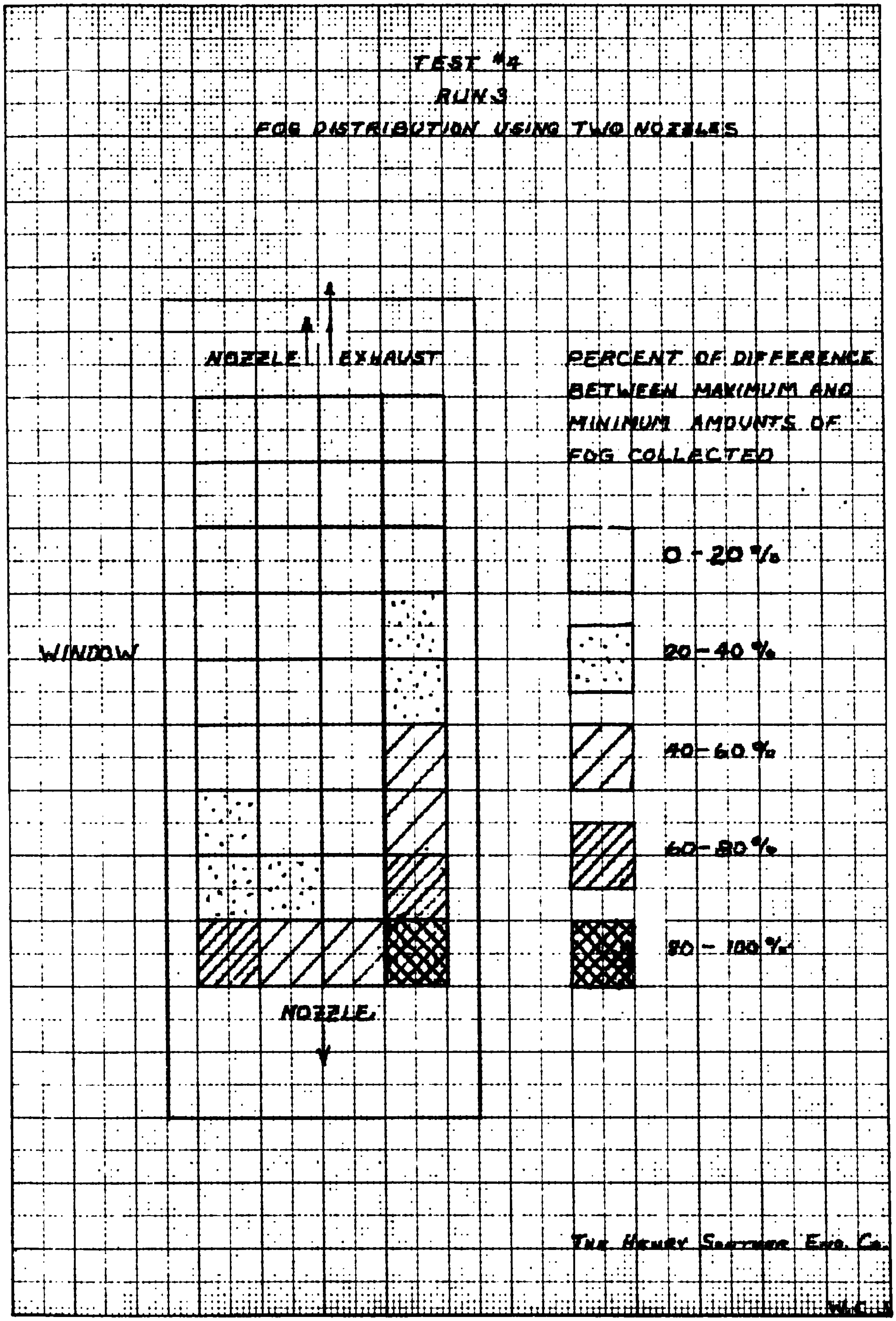
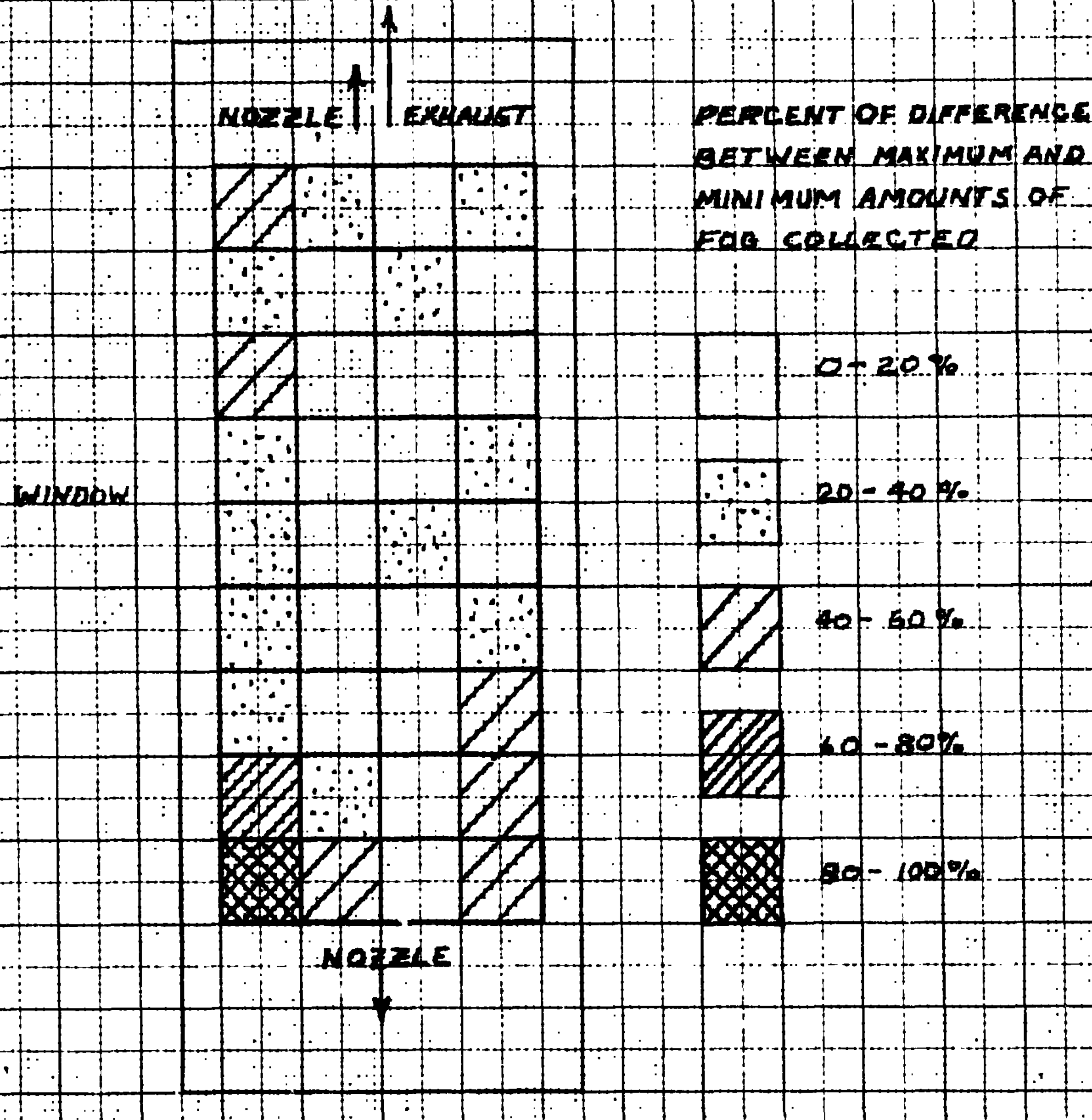
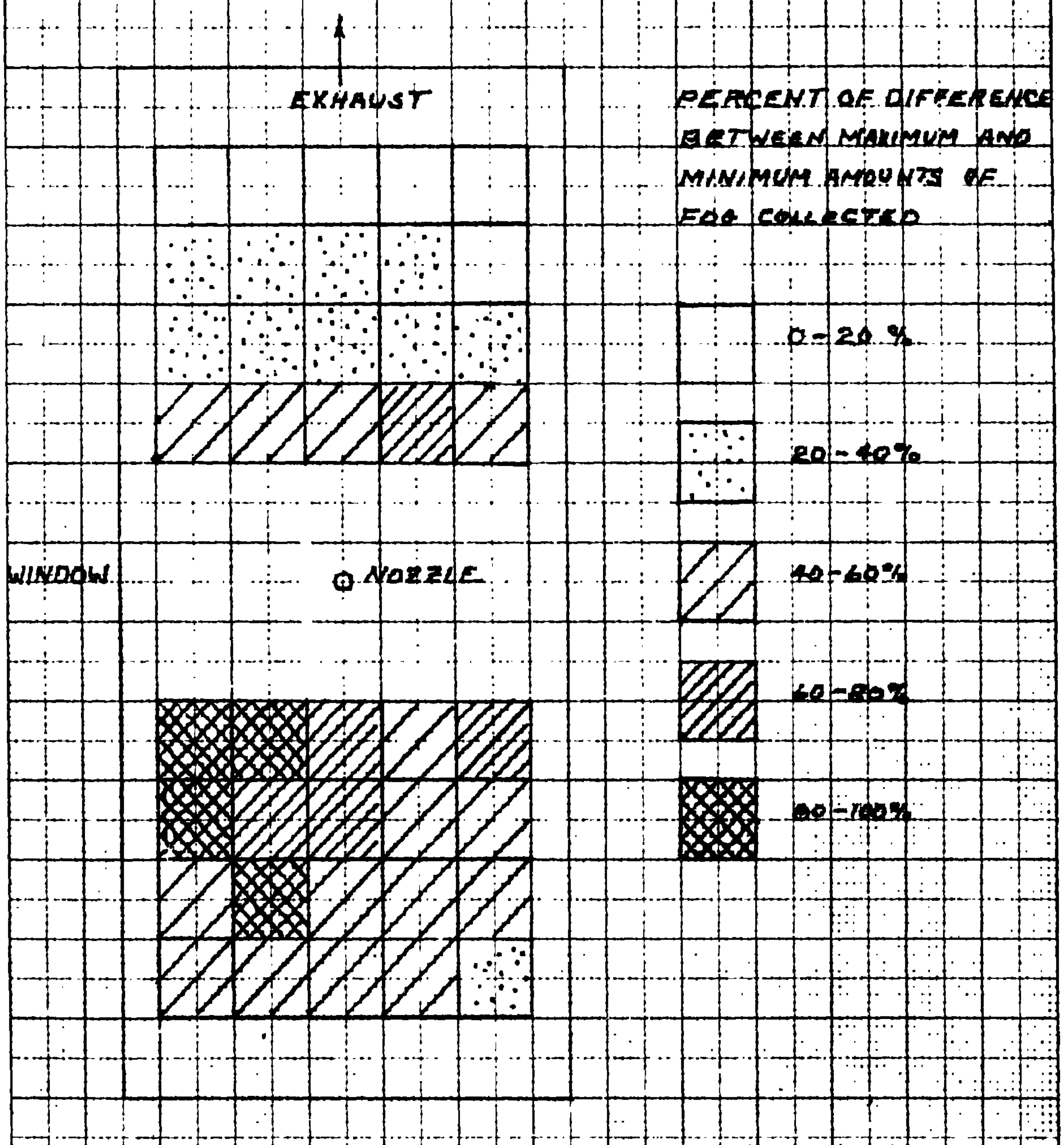

TEST #4
RUN 3
FOG DISTRIBUTION USING TWO NOZZLES
NOZZLE
EXHAUST
PERCENT OF DIFFERENCE BETWEEN MAXIMUM AND MINIMUM AMOUNTS OF FOG COLLECTED
0 - 20 %
20 - 40 %
40 - 60 %
60 - 80 %
80 - 100 %
WINDOW
NOZZLE
THE HENRY SOUTHER ENG. CO.
W.C.B.

TEST #4
RUN 4
REPEAT OF RUN 3



THE HENRY SOUTHER ENG. CO.

TEST #4
RUN 5
FOG DISTRIBUTION WITH
LOWERED COVER



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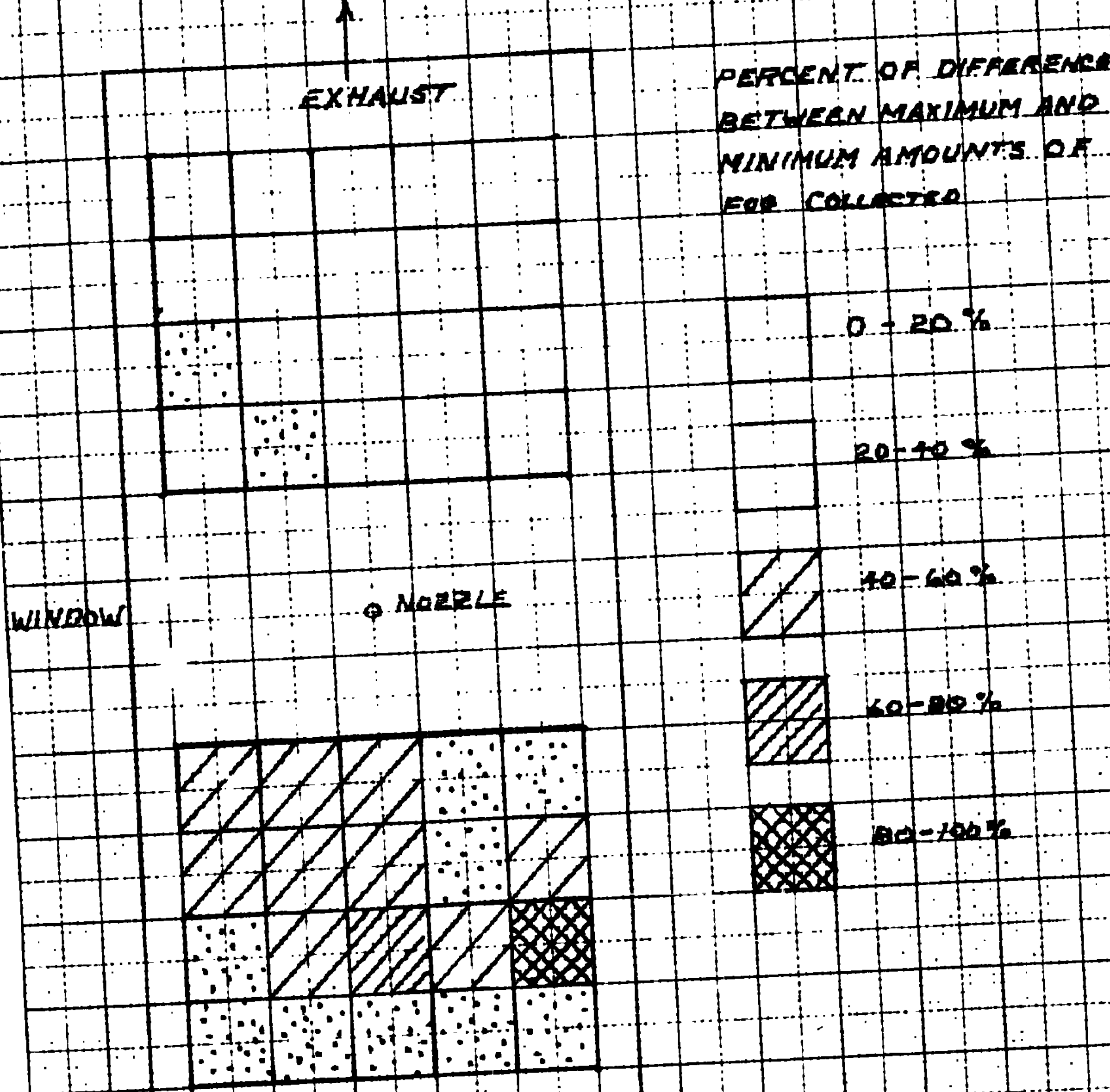
WCJ

TEST #4
RUN 6
FOG DISTRIBUTION WITH ELEVATED
COVER



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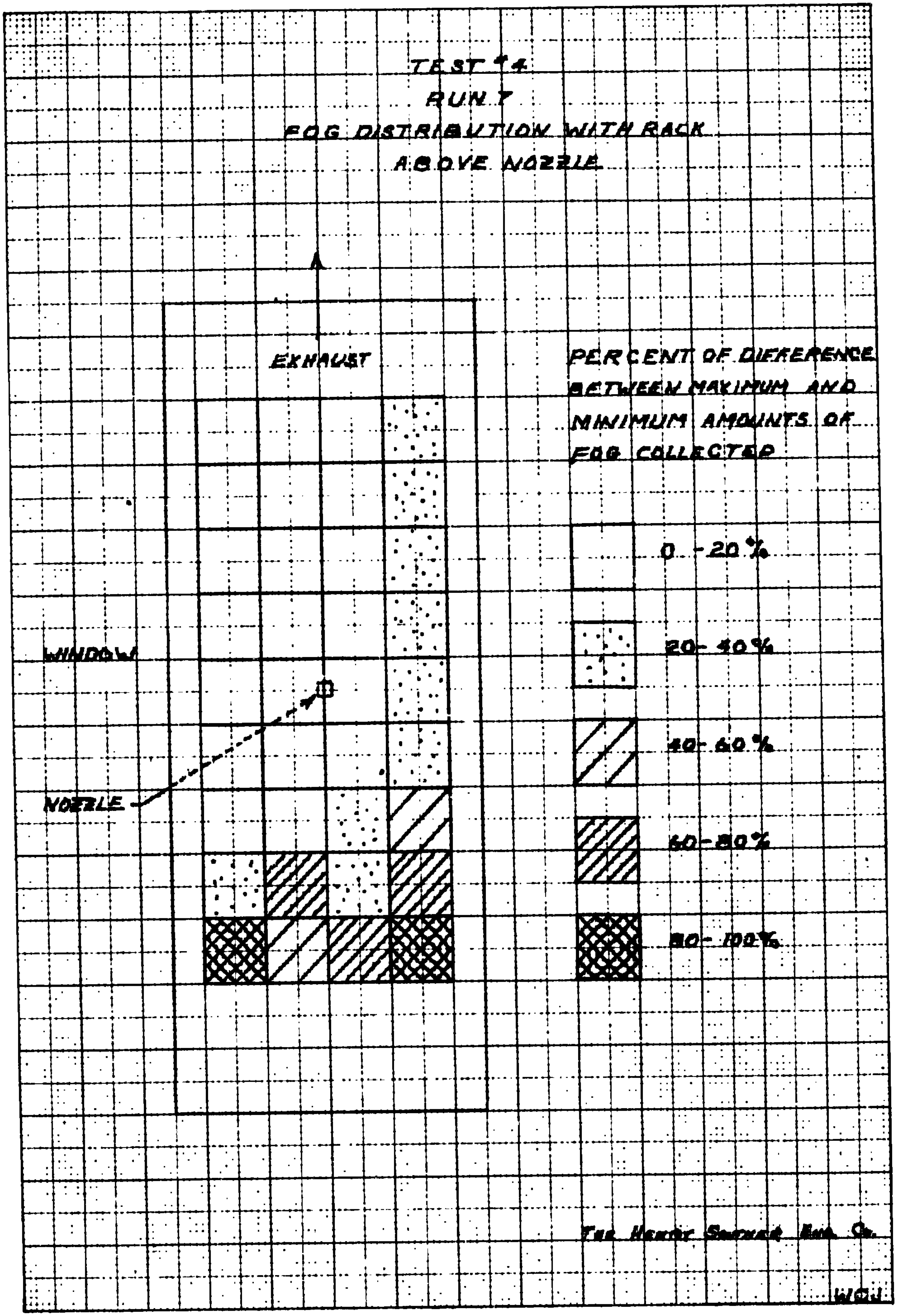
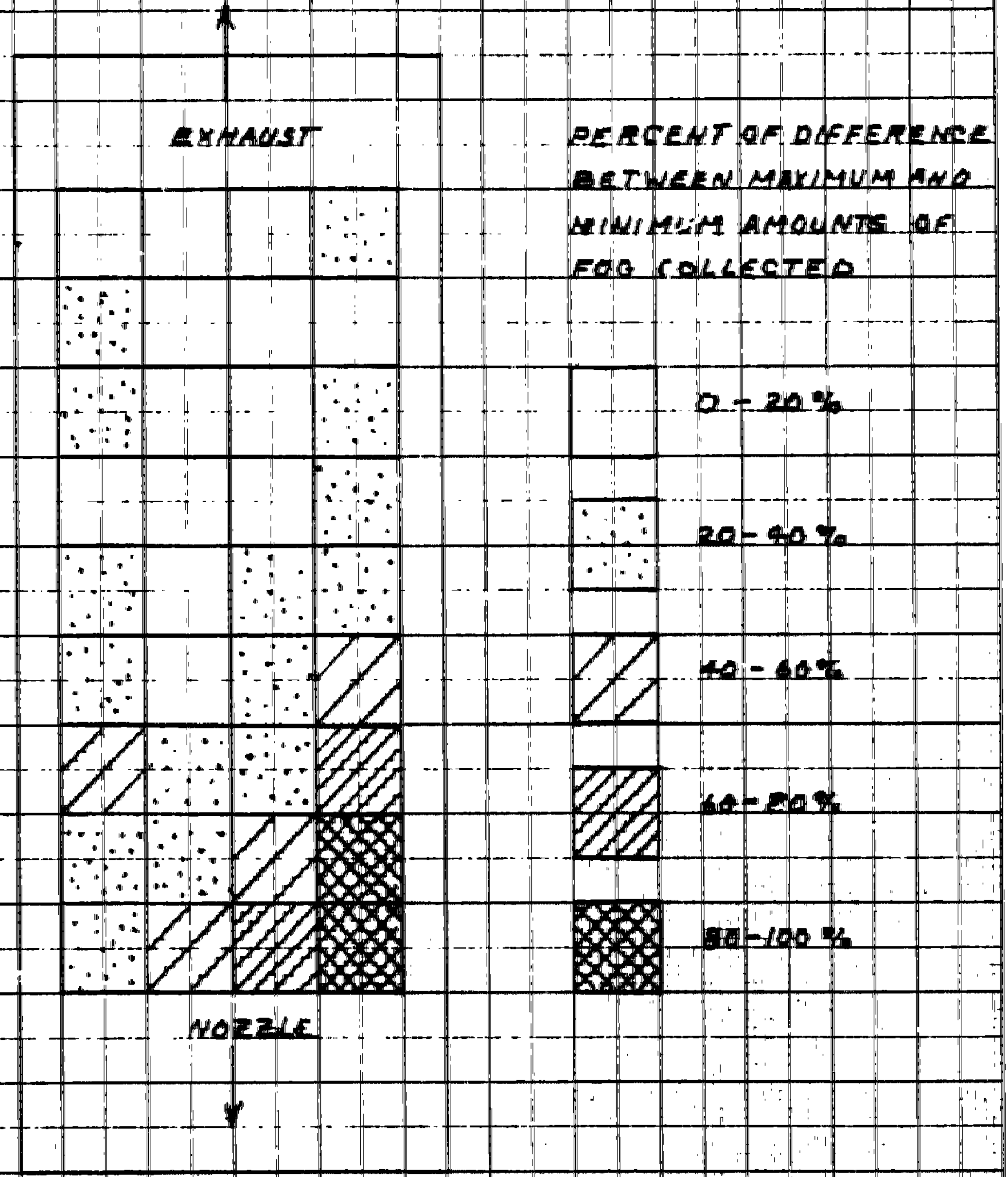
WGJ


TEST #4
RUN 7
FOG DISTRIBUTION WITH RACK
ABOVE NOZZLE
EXHAUST
WINDOW
NOZZLE
PERCENT OF DIFFERENCE
BETWEEN MAXIMUM AND
MINIMUM AMOUNTS OF
FOG COLLECTED
0 - 20%
20 - 40%
40 - 60%
60 - 80%
80 - 100%
THE HENRY SOUTHER ENG. CO.

TEST #4
RUN 8
FOG DISTRIBUTION WITH 5 LB. PRESSURE



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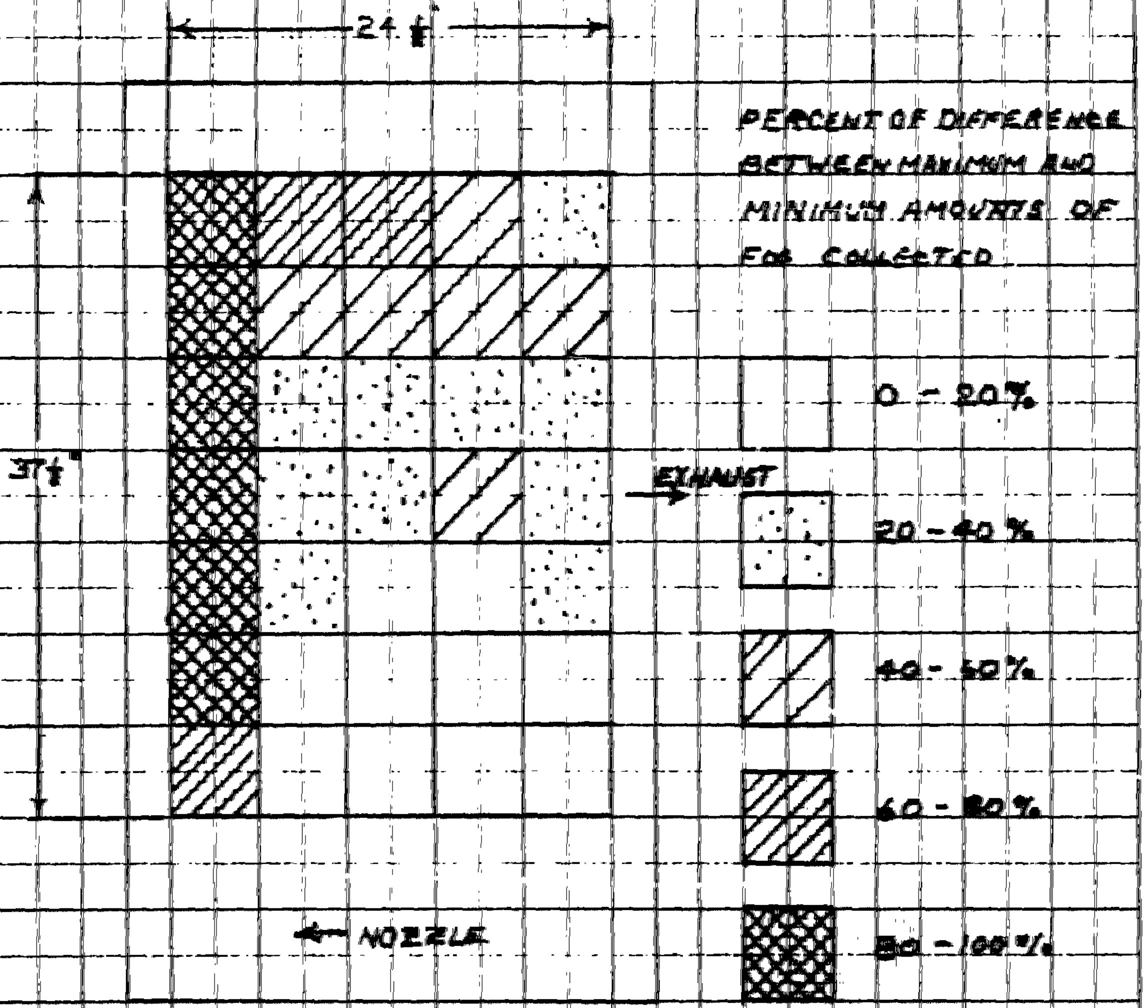
W.E.L.

TEST #4

RUN 9

FOG DISTRIBUTION IN A COMMERCIAL SALT SPRAY CABINET



CABINET MADE BY —
INDUSTRIAL FILTER & PUMP MFG. CO.
SERIAL NO. - S-1540
TYPE - CA1

The [illegible] [illegible] Eng. Co.

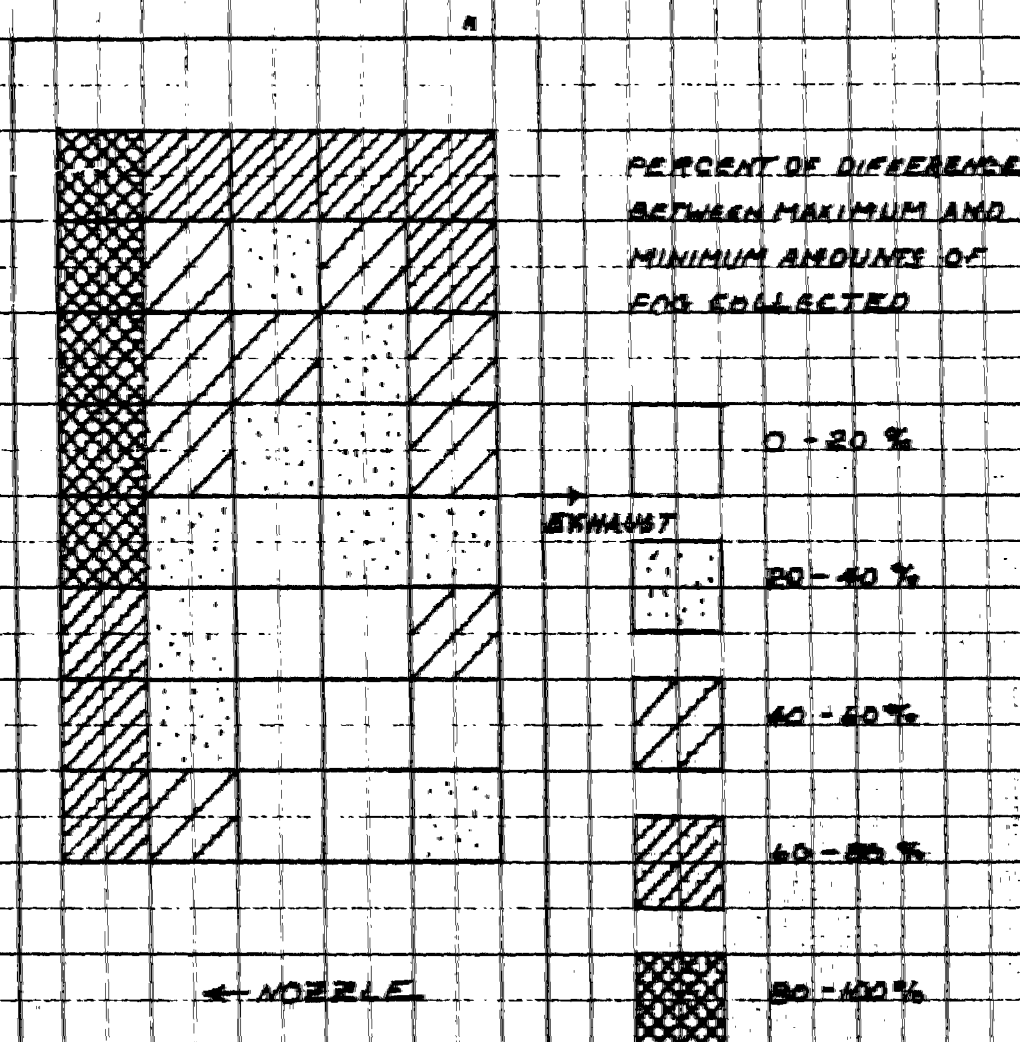
WC.1

TEST #9

RUN 10

REPEAT OF RUN 9

FOG DISTRIBUTION IN A COMMERCIAL SALT SPRAY CABINET



The Henry Souther Eng. Co.

W.G.J.

TEST NO. 5

Object

The object of this phase of the investigation is to determine the distribution of amount of corrosion of steel panels in a salt fog atmosphere.

Summary

A test has been run at 95°F, using a 20% salt solution, to determine the amount of corrosion of steel panels in the different parts of the test area of the salt spray cabinet.

Introduction

In the foregoing tests, an investigation was conducted to correlate the amount of corrosion of a steel panel with the fog density at that position in the cabinet. Fog distribution patterns were determined and wide variations were observed. The amount of corrosion varied, in general, inversely as the amount of fog collected. All these runs were made using water and not a salt solution. Since most of the tests using this cabinet are to be made with salt solutions, the distribution of corrosion in such an atmosphere should be checked on panels of like material before comparison can be made, in subsequent runs, between panels of different composition.

Conclusions

On the basis of this test, it is evident that the corrosion rate and distribution are more even than those in the foregoing tests, using distilled water. The distribution of corrosion as measured in the outlined manner appears to be such that comparative test can be made with dissimilar test panels and that reasonable conclusions can be drawn regarding corrosion rates regardless of the position of the test panel in the box.

TEST NO. 6

Object

The object of this test is to determine the corrosive effects of a 20% sodium chloride solution, pH 7.0 at 100°F, on steel, brass, zinc, aluminum, cadmium, nickel plate, and enameled and phosphated steel.

Summary

A test has been conducted for a period of 200 hours in the salt spray test cabinet to determine the effect of increasing the temperature 5°F above the standard value of 95°F. Operating conditions were: temperature 100°F, 20% salt solution at pH 7.0.

Introduction

"The test shall be conducted with a temperature in the exposure zone maintained at 95° plus 2° or minus 3°F." - Federal Specification QQ-M-151a. The maintenance of the proper operating temperature should be an important factor in determining the corrosion rate of metals and protective coatings because of the increase in reaction rate of most chemical changes with an increase in temperature. In this and subsequent tests, the temperature will be varied over the range of practically encountered temperatures, and its effect on the corrosion rate determined.

Procedure

The test was run for 200 hours, using a 20% sodium chloride solution at pH 7.0. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a fairly consistent rate, while the brass panels, after an initial loss in two cases, gained weight steadily. The zinc panels, although more irregular in their day to day weights, showed a net loss in weight, whereas the cadmium panels attained a practically steady weight after the first 24 hours of exposure. The enameled panels and the sulfuric acid anodized panels showed little evidence of attack after the 200 hours. The chromic acid anodized aluminum panels showed definite evidence of corrosion after 176 hours exposure. The nickel plated steel panels all failed after one hour exposure, three failing after one-half hour. The phosphated steel panels showed no evidence of rusting after one-half hour, but all failed before one hour in the test cabinet.

Conclusions

These data collected during this run will be used as a measure of the corrosion rate at 100°F, 20% sodium chloride, pH 7.0.

APPENDIX A

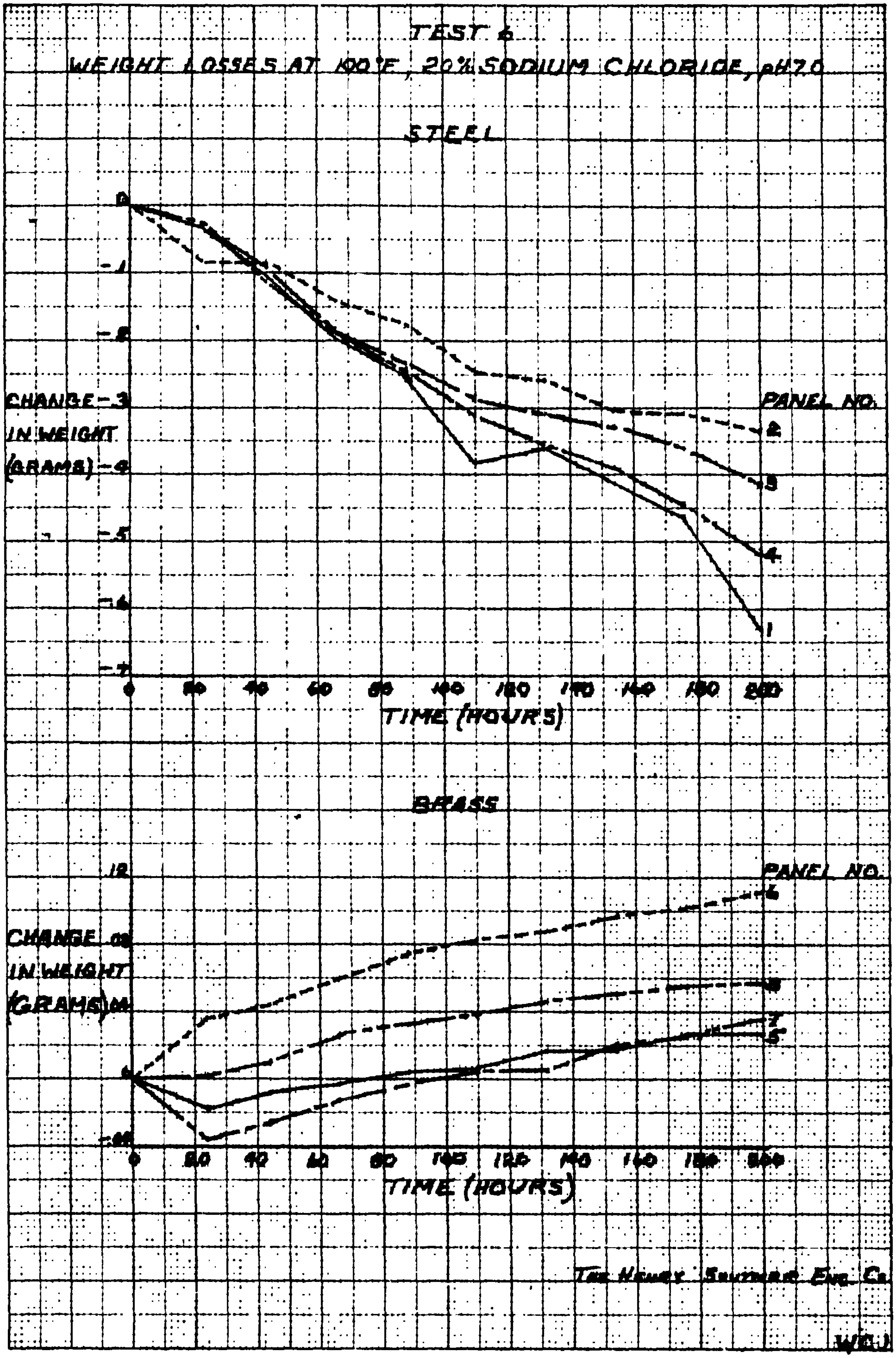
CORROSI N RATES AT 100° F., 20% SODIUM CHLORIDE

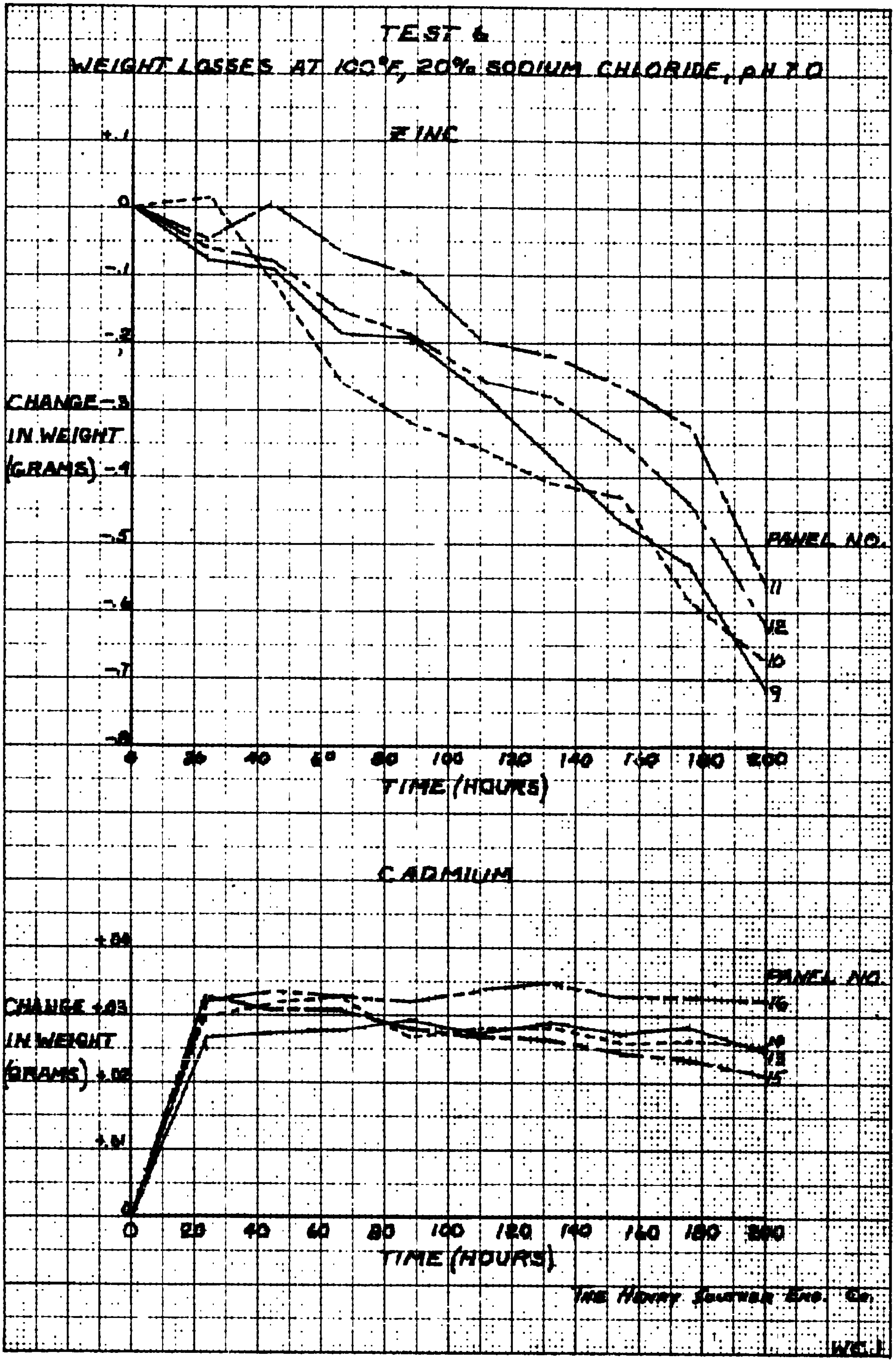
LENGTH OF TEST – 200 hours

re – 100° F.

	1/1/52 20% NaCl	1/2/52 20% NaCl	1/3/52 20% NaCl	1/4/52 20% NaCl	PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	154 hrs.	176 hrs.	200 hrs.
1 I										CUMULATIVE WEIGHT LOSSES (grams) and RATINGS								
					Steel													
					1					.0305	.1060	.1985	.2504	.3318	.3672	.4091	.4547	.5321
					2					.0815	.0827	.1412	.1781	.2450	.2551	.3018	.3089	.3348
	99°	98°	99°	99°	3					.0512	.0899	.1836	.2305	.2642	.3069	.3279	.3605	.4116
					4					.0260	.1016	.1811	.2421	.3145	.3547	.3395	.4422	.5132
					Brass													
	99°	98°	99°	99°	5					.0178	.0080	.0033	-.0041	-.0065	-.0170	-.0169	-.0267	-.0274
					6					-.0360	-.0431	-.0693	-.0736	-.0820	-.0883	-.0972	-.1022	-.1127
					7					.0362	.0253	.0127	.0042	-.0047	-.0047	-.0204	-.0260	-.0362
	100%	100%	100%	100%	9					-.0014	-.0099	-.0267	-.0319	-.0384	-.0466	-.0502	-.0534	-.0565
					Zinc													
					9					.0717	.0909	.1371	.1905	.2723	.3704	.4632	.5290	.7144
	.5	.5	.5	.5	10					-.0113	.1072	.2532	.3169	.3537	.4100	.4265	.5863	.6663
					11					.0422	-.0009	.0665	.0966	.1969	.2174	.2674	.3268	.5631
					12					.0575	.0796	.1552	.1825	.2535	.2757	.3478	.4404	.6233
6	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}	Cadmium													
					13					-.0267	-.0272	-.0273	-.0298	-.0272	-.0290	-.0273	-.0283	-.0249
					14					-.0297	-.0316	-.0324	-.0267	-.0280	-.0289	-.0257	-.0265	-.0257
	9.5	9.5	12	12	15					-.0329	-.0306	-.0309	-.0279	-.0269	-.0268	-.0244	-.0234	-.0216
					16					-.0322	-.0331	-.0328	-.0320	-.0338	-.0347	-.0322	-.0322	-.0324
					Enamel													
	95°	95°	95°	95°	17					10/10	10/10	10/10	10/10	10/10	9.5/s/9.5	9/s/9	9/s/9	9/s/9
					18					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
					19					10/10	10/10	10/10	10/10	10/10	10/10	10/10	9/s/9	9/s/9
	.46	.46	.55	.55	20					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
					Anodized Aluminum (H_2SO_4)													
	7.0	7.0	7.0	7.0	21					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
					22					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	6.8	6.8	6.8	6.8	23					10/10	10/10	10/10	10/10	10/10	10/10	9.5/d/9	9.5/d/9	9.5/d/9
					24					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	1.6	1.7	1.8	1.8	Anodized Aluminum (CrO_3)													
					25					10/10	10/10	10/10	10/10	10/10	10/10	10/10	7/s/9	7/s/9
					26					10/10	10/10	10/10	10/10	10/10	10/10	10/10	5/s/9	4.5/s/9
					27					10/10	10/10	10/10	10/10	10/10	10/10	10/10	6/s/9	6/s/9
					28					10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	99.8%	99.8%	99.8%	99.8%	Nickel-plated Steel													
	—	—	—	—	29	10/10	Failed											
	—	—	—	—	30	Failed												
	1.150	1.150	1.150	1.150	31	Failed												
					32	Failed												
	5 gal.	5 gal.	5 gal.	5 gal.	Phosplated Steel													
					33	10/10	Failed											
					34	10/10	Failed											
					35	10/10	Failed											
					36	10/10	Failed											

APPENDIX B


TEST 6
WEIGHT LOSSES AT 100°F, 20% SODIUM CHLORIDE, pH7.0
STEEL
CHANGE IN WEIGHT (GRAMS)
0
-1
-2
-3
-4
-5
-6
-7
PANEL NO.
2
3
4
1
0
20
40
60
80
100
120
140
160
180
200
TIME (HOURS)
BRASS
CHANGE IN WEIGHT (GRAMS)
.12
.08
.04
0
-.04
PANEL NO.
6
8
7
5
0
20
40
60
80
100
120
140
160
180
200
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.
WEJ


TEST 6
WEIGHT LOSSES AT 100°F, 20% SODIUM CHLORIDE, pH 7.0
ZINC
CHANGE IN WEIGHT (GRAMS)
+.1
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
PANEL NO.
11
12
10
9
0 20 40 60 80 100 120 140 160 180 200
TIME (HOURS)
CADMIUM
CHANGE IN WEIGHT (GRAMS)
+.04
+.03
+.02
+.01
0
PANEL NO.
16
14
13
15
0 20 40 60 80 100 120 140 160 180 200
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.
WG. 1

TEST NO. 7

Object

The object of this test and one of the primary objects of this investigation is to determine the effect of various physical operating conditions on the corrosion rates of various materials in a salt spray cabinet.

Introduction

As a basis for comparison this test was run in accordance with Specification ASTM B117-49T (similar to QQ-M-151a) for temperature, air pressure and solution composition. From results obtained in this test, comparisons of corrosion resistance can be made when conditions are varied.

Conclusions

The test panels, in general, followed the expected pattern of salt spray resistance. The length of time to failure for the various materials will be used as a basis for comparison with those obtained in subsequent tests.

Procedure

Thirty-six panels, four each of nine different materials, were used in this test as summarized below. The same number and types of panels will be used in the following tests:

2 x 3"	Steel panels SAE 1030
3 x 9"	Brass panels 70% copper, 30% zinc
3 x 9"	Zinc panels
2 x 3"	Cadmium panels
3 x 10"	Aluminum panels, chromic acid anodized
3 x 10"	Aluminum panels, sulfuric acid anodized
2 x 3"	Phosphated (manganese) steel panels
3 x 8"	Nickel plated (.001") steel panels
4 x 10"	Steel panels, phosphated and then coated with two coats of black enamel as described in Part 1 of this report.

The steel, brass and zinc panels were abraded with a 240-grit Aloxite metal cloth, using an oscillating electric sander. They were then cleaned with A-1 cleaner, water-rinsed, dried at 110°C, cooled and weighed to the nearest tenth of a milligram.

Difficulty was encountered in attempting to abrade the cadmium panels due to the soft nature of the metal. These panels were dipped in a 2% hydrochloric acid solution at room temperature for five minutes and water-rinsed prior to weighing. The anodized aluminum, phosphated, nickel plated and enameled panels were placed in the salt spray box without any additional cleaning operation.

The steel, brass and zinc panels were removed from the box every 24 hours. They were scrubbed with a stiff nylon bristle brush under running water until no more corrosion product could be removed as indicated by visual inspection. They were then dried and weighed as before.

Previous experience has shown that the corrosion products of cadmium adhere tenaciously to the metal and are not really soluble in water. As a result of tests conducted and elsewhere described in this report, the cadmium panels were cleaned by immersion in a 2% sodium cyanide solution for five minutes at room temperature followed by a water rinse.

A visual rating system was employed to evaluate the anodized aluminum, nickel plated steel, phosphated and enameled panels as described in the ASTM article - "A Visual System for Rating Panels."

Observations were made on the phosphated steel and nickel plated panels after 1/2, 1, 1-1/2 and 2 hours, and all panels were observed every 24 hours. The observations and weight losses appear in Appendix A.

The box was operated at 95°F and a 20% salt solution was used. The pH of the solution was adjusted to 7.0. The operating conditions and physical values mentioned are also summarized in Appendix A.

The cumulative weight losses were calculated and plots of these values versus the corresponding days are in Appendix B. The tests were limited to 200 hours duration since the data required for evaluation were obtained well within this time limit.

Discussion

The steel panels lost weight at a fairly constant rate. The values diverged in increasing amount with increasing time. Variations from a constant rate of corrosion can possibly be ascribed to incomplete removal of corrosion products on individual days.

The brass panels all lost weight during the first 24 hours and then gained steadily, although not constantly for the remainder of the test. At 120 hours, all the panels equalled or exceeded the original weight at the start of the test. The changes in weight were only approximately one-tenth those for the steel panels, although the brass panels have 4-1/2 times the surface area of the steel panels.

The zinc panels lost weight at a relatively steady rate and were heavily streaked with white corrosion products, all of which could not be removed by scrubbing.

The enameled panels stood up well, as was to be expected. Slight rust along the edges and a few rust spots were noted as shown in detail in Appendix A.

The phosphated steel panels all failed at the end of 2 hours - one failing at 1 hour and two at 1-1/2 hours.

Conclusions

These test results are to be used as a standard for comparison when deviations from standard practice are made.

METHOD OF RATING PANELS*

Rating of 3" x 10" Chromic Acid and Sulfuric Acid Anodized Aluminum Panels

Numerical Rating	Corrosion Dots	Corrosion Spots	Corrosion Areas
10	No corrosion	No corrosion	No corrosion
9	10	5	2.5 small areas
7	20	10	5 small areas
5	40	20	10 small areas
3	80	40	20 small areas
1	160	80	40 small areas
0	Complete Corrosion		

Rating of 4" x 10" Enameled Panels

10	No corrosion	No corrosion	No corrosion
9	15	6	3 small rust areas
7	26	13	6 small rust areas
5	53	26	13 small rust areas
3	213	106	53 small rust areas
1	426	213	106 small rust areas
0	Complete Corrosion		

Rating of 3" x 8" Nickel-Plated Steel Panels

1 rust spot in 24 square inches constitutes failure.

Rating of Phosphated Steel Panels

First sign of rust constitutes failure.

*Based on "A Visual Rating System for Rusted Steel Specimens" by Harry L. Faigen. Authorized reprint from the Copyrighted ASTM Bulletin No. 154 October, 1948.

Object

The object of this investigation is to develop an effective method for cleaning cadmium test panels after their exposure in the salt spray test cabinet.

Summary

Tests have been conducted to evaluate the effectiveness of soaking the cadmium panels in a dilute cyanide solution as a method for the removal of corrosion products adhering to the surface of the panels.

Introduction

When cadmium panels were exposed in the salt spray cabinet, there was an initial buildup of corrosion products on the surface as indicated by a sharp gain in weight during the first 24 hours of exposure. After that, the weights remained practically constant on successive days despite thorough scrubbing with a stiff nylon bristle brush under running water. This is probably due to the formation of a film of cadmium oxide on the surface which adheres tenaciously enough so that it cannot be removed by scrubbing. A dilute solution of sodium cyanide was used to dissolve the coating, and results of an investigation of this method are summarized below.

Procedure

Four cadmium panels were cleaned in 5% hydrochloric acid for 5 minutes, rinsed under running water, dried in a forced air oven at 110°C, cooked, and weighed to the nearest tenth of a milligram. They were exposed to laboratory air for 24 hours and then immersed in a 2% solution of sodium cyanide for 5 minutes, rinsed with running water and dried as before. This process of exposure and cyanide cleaning was repeated over a period of 12 days. A summary of the individual day to day changes in weight along with the average and standard deviation is attached.

Discussion

From the data in the summary, the weight losses incurred appear to be insignificant especially when compared with the results obtained with cadmium panels and exposure to salt spray as shown in the salt spray tests, starting with Test No. 7.

Conclusion

The method of cleaning the cadmium panels as outlined appears to be satisfactory and has been adopted as a routine procedure.

CADMIUM WEIGHT LOSSES

Panel No.	Day	1	2	3	4
	1	.0009	.0012	.0008	.0005
	2	.0005	.0004	.0007	.0005
	3	.0005	.0000	.0005	.0003
	4	+.0003	.0007	.0000	.0011
	5	.0006	.0001	.0001	.0001
	6	+.0010	.0009	+.0008	+.0014
	7	.0000	.0001	.0002	.0001
	8	.0000	.0001	.0001	.0005
	9	.0002	.0000	.0001	.0007
	10	.0000	.0003	.0002	.0007
	11	.0003	.0000	.0002	.0002
	12	.0003	.0000	.0000	.0004
Average		.000167	.000317	.000175	.000308
Standard Deviation		.000174	.000365	.000364	.000583

APPENDIX A

TEST NUMBER 7 -

DATES	1/15/52	1/16/52	1/17/52	1/18/52	1/19/52	1/20/52	1/21/52	1/22/52
					VARIABLE - Temperature - 95° F.			
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp.(° F.)	95°	94°	94°	94°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	94°	94°	94°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (mm./sec.)	5×10^{-5}	5×10^{-5}	5×10^{-5}	5×10^{-5}	5×10^{-5}	5×10^{-5}	5×10^{-5}	5×10^{-5}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12	12
Room Temp. (° F.)	90°	90°	90°	90°	90°	90°	90°	90°
Rate of Flow (ft.^{3}/min.)	.48	.48	.48	.48	.48	.48	.48	.48
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Rate of Fog Collection (mls./hr.)	.9	1.1	1.2	.8	.5	1.0	1.0	1.0
Impurities in Salt Solution								
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	——	——	——	——	——	——	——	——
3. Heavy Metals	——	——	——	——	——	——	——	——
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 h
						CUMULATIVE W	
Steel							
1					.0666	.1438	.20
2					.0478	.1108	.15
3					.0447	.1004	.16
4					.0683	.1233	.20
Brass							
5					.0103	.0014	.00
6					.0543	.0384	.02
7					.0576	.0484	.02
8					.0529	.0084	-.00
Zinc							
9					.0622	.1207	.20
10					.0554	.0942	.17
11					.0668	.1174	.21
12					.0708	.1198	.18
Cadmium							
13					.0627	.1033	.15
14					.0591	.1015	.15
15					.0650	.1068	.14
16					.0510	.1024	.12
Enamel							
17					10/10	9.5/e/9.5	9.5/
18					10/10	9.5/e/9.5	9.5/
19					10/10	9.5/e/9.5	9.5/
20					10/10	9.5/e/9.5	9.5/
Anodized Aluminum (H_2SO_4)							
21					Failed		
22					Failed		
23					8/ds/9	6/ds/9	6/d
24					Failed		
Anodized Aluminum							
25					10/10	10/10	8/d
26					10/10	10/10	10/
27					10/10	10/10	6/d
28					10/10	10/10	10/
Nickel-plated Steel							
29	10/10	10/10	10/10	Failed			
30	10/10	10/10	10/10	10/10	Failed		
31	10/10	10/10	10/10	10/10	Failed		
32	10/10	10/10	10/10	Failed			
Phosphated Steel							
33	10/10	Failed					
34	10/10	10/10	Failed				
35	10/10	10/10	Failed				
36	10/10	10/10	10/10	Failed			

ature - 95° F.

1/52 NaCl	1/22/52 20% NaCl
95°	95°
95°	95°
100%	100%
.5	.5
3×10^{-5}	3×10^{-5}
12	12
90°	90°
.48	.48
7.0	7.0
6.8	6.8
1.0	1.0
99.8%	99.8%
——	——
——	——
1.150	1.150
5 gal.	5 gal.

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

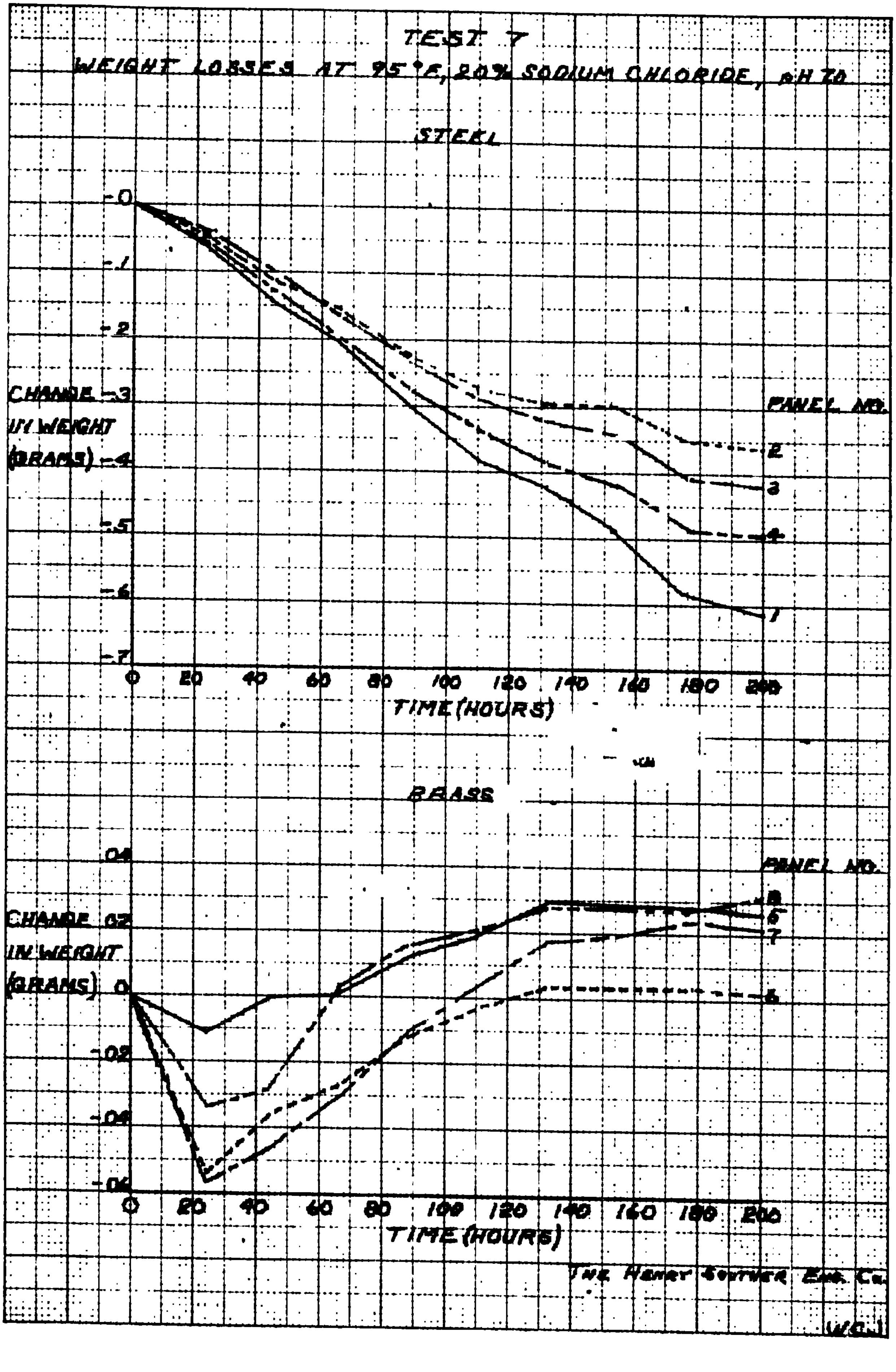
LENGTH OF TEST - 200 hours

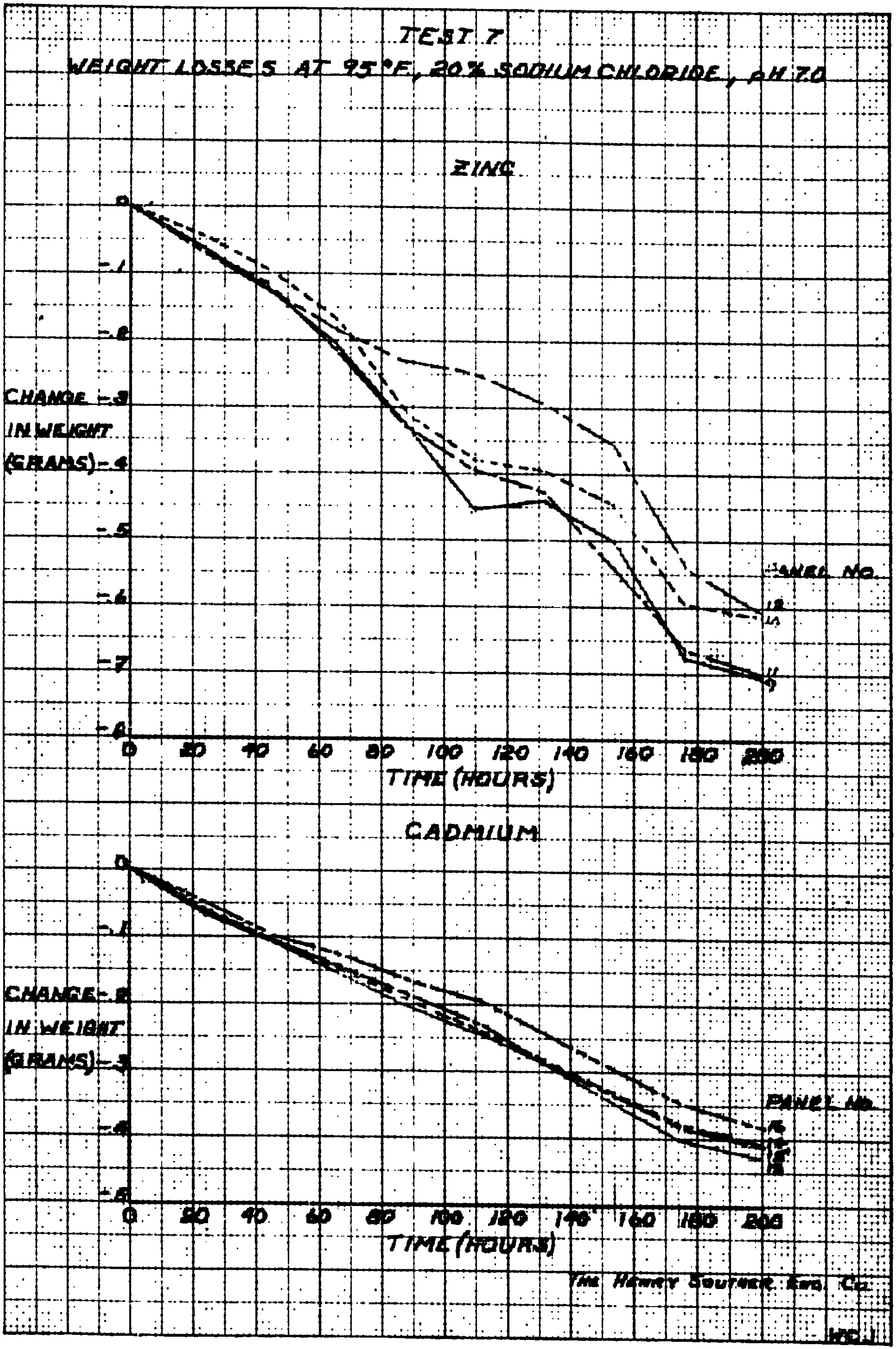
CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	154 hrs.	176 hrs.	200 hrs.
Steel													
1					.0666	.1438	.2067	.2971	.3759	.4190	.4378	.5821	.6051
2					.0478	.1102	.1535	.2228	.2696	.2905	.3000	.3491	[illegible]
3					.0447	.1004	.1613	.2768	.2859	.3185	.3366	.4034	.4108
4					.0585	.1233	.2025	.2735	.3348	.3814	.4175	.4596	.4308
Brass													
5					.0137	.0014	.0001	-.0120	-.0185	-.0235	-.0282	-.0282	[illegible]
6					.0543	.0374	.0271	.0121	.0036	-.0038	-.0035	-.0080	-.0020
7					.0576	.0464	.0299	.0139	-.0033	-.0171	-.0194	-.0257	-.0206
8					.0520	.0084	-.0017	-.0158	-.0204	-.0280	-.0267	-.0262	-.0300
Zinc													
9					.0622	.1207	.2063	.3277	.4530	.4397	.5012	.6792	.7076
10					.0554	.0942	.1701	.3104	.3749	.3965	.4469	.5943-	.6088
11					.0688	.1174	.2175	.3370	.3919	.4237	.5410	.6665	.5992
12					.0708	.1193	.1406	.2356	.2475	.2090	.3581	.5575	.6131
Cadmium													
13					.0627	.1033	.1548	.2030	.2307	.2907	.2541	.3988	.4273
14					.0501	.1015	.1501	.1965	.2370	.2849	.3354	.3792	.4050
15					.0630	.1069	.1463	.1366	.2285	.2864	.3370	.3950	.4064
16					.0510	.1024	.1250	.1612	.1940	.3458	.2941	.3422	.3788
Enamel													
17					10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
18					10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
19					10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
20					10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
Anodized aluminum (H_2SO_4)													
21					Failed								
22					Failed								
23					3/ds/9	6/ds/9	6/ds/9	6/ds/9	4/ds/9	4/ds/9	Failed		
24					Failed								
Anodized Aluminum													
25					10/10	10/10	8/ds/9	[illegible]/ds/9	4/ds/9	2/ds/9	Failed		
26					10/10	10/10	10/10	10/10	2/ds/9	2/ds/9	Failed		
27					10/10	10/10	8/ds/9	6/ds/9	4/ds/9	4/ds/9	Failed		
28					10/10	10/10	10/10	10/10	2.5/ds/9	2.5/ds/9	Failed		
Nickel-plated Steel													
29	10/10	10/10	10/10	Failed									
30	10/10	10/10	10/10	10/10	Failed								
31	10/10	10/10	10/10	10/10	Failed								
32	10/10	10/10	10/10	Failed									
Phosphated Steel													
33	10/10	Failed											
34	10/10	10/10	Failed										
35	10/10	10/10	Failed										
36	10/10	10/10	10/10	Failed									

2

APPENDIX B


TEST 7
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0
STEEL
CHANGE IN WEIGHT (GRAMS)
-0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
PANEL NO.
2
3
4
1
0
20
40
60
80
100
120
140
160
180
200
TIME (HOURS)
BRASS
CHANGE IN WEIGHT (GRAMS)
.04
.02
0
-.02
-.04
-.06
PANEL NO.
8
5
7
6
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.


TEST 7
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0
ZINC
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
0
20
40
60
80
100
120
140
160
180
200
TIME (HOURS)
PANEL NO.
CADMIUM
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
-.4
-.5
0
20
40
60
80
100
120
140
160
180
200
TIME (HOURS)
PANEL NO.
THE HENRY SOUTHER ENG. CO.
FIG. 1

TEST NO. 8

Object

The object of this test is to determine the corrosive effects of a 20% sodium chloride solution, pH 7.0 at 70°F on the nine materials described in Test No. 7.

Summary

A test has been conducted for a period of 150 hours in the salt spray test cabinet to determine the effect of decreasing the temperature 25°F below the standard value of 95°F. The concentration of the salt solution and its pH as well as the operating conditions of the box were maintained the same as in Test No. 7.

Introduction

70°F approximates room temperature and, therefore, the lowest conveniently obtained temperature for the operation of a salt spray test cabinet. Corrosion rates at this temperature obtained in this test will be compared to those at elevated temperatures.

Procedure

A procedur similar to that described in Test No. 7 was followed. The test was limited to 150 hours, using a 20% sodium chloride solution at pH 7.0. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A, and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight consistently. It is interesting to note that in Tests 6, 7 and 8, the order in which the panels lost weight (2, 3, 4, 1) is the same. This is probably due to their position in the box. (See plot of positions given in Appendix B of Test No. 1)

The brass panels lost weight during the first 24 hours and then gained as has been previously experienced. The zinc panels, however, showed a slight increase in weight compared with a marked decline experienced at the higher temperature.

The cadmium panels lost consistently and their weight losses were grouped closely together.

The enameled panels showed little evidence of corrosion at the end of the 150 hours.

The chromic acid anodized aluminum panels proved superior to those prepared by the sulfuric acid process, although the difference was not as great as had been experienced at higher temperatures.

The nickel plated specimens all failed before 24 hours exposure, and the phosphated steel panels failed before 2 hours.

Conclusions

These data constitute a measure of the corrosion rate at 70°F, 20% sodium chloride, pH 7.0. The results will be used to determine the effect of concentration of salt solution and temperature on the corrosion rate.

APPENDIX A

TEST NUMBER 8

CORROSION RATES AT 70° F., 20% SODIUM CHLORIDE, pH 7.0

DATES	1/24/52	1/25/52	1/26/52	1/27/52	1/28/52	1/29/52	1/30/52
	VARIABLE - Temperature - 70° F.						
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp.(° F.)	70°	70°	[illegible]°	70°	70°	70°	70°
Wet Bulb Temp.(° F.)	70°	70°	70°	70°	70°	70°	70°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (cm./sec.)	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12
Room Temp. (° F.)	71°	71°	71°	71°	71°	71°	71°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.46	.46
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	6.3	6.3	6.3	6.3	6.9	6.3	6.8
Rate of Fog Collection (mls./hr.)	1.0	.9	.9	.9	.9	.9	.9
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	—	—	—	—	—	—	—
3. Heavy Metals	—	—	—	—	—	—	—
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

LENGTH OF TEST -

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.
					CUMULATIVE WEIGHT LOSSES (grams) and			
Steel								
1					.0330	.0942	.1250	.1311
2					.0244	.0730	.1008	.1304
3					.0239	.0665	.0998	.1432
4					.0245	.0720	.0940	.1410
Brass								
5					.0258	.0247	.0127	.0111
6					.0221	.0144	.0036	-.0029
7					.0323	.0244	.0102	.0094
8					.0250	.0154	.0057	.0006
Zinc								
9					-.0310	.0185	-.0151	.0087
10					.0472	.0153	-.0540	-.0091
11					-.0039	.0257	-.0498	.0045
12					-.0514	.0063	-.0514	-.0400
Cadmium								
13					.0482	.0960	.1331	.1928
14					.0320	.0907	.1331	.1658
15					.0361	.0911	.1328	.1755
16					.0320	.0841	.1335	.1789
Enamel								
17					10/10	10/10	10/10	10/10
18					10/10	10/10	10/10	10/10
19					10/10	10/10	10/10	10/10
20					10/10	10/10	10/10	10/10
Anodized Aluminum (H_2SO_4)								
21					10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10
23					10/10	10/10	10/10	10/10
24					10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)								
25					10/10	10/10	10/10	10/10
26					10/10	10/10	10/10	10/10
27					10/10	6/s/7	6/s/7	6/s/7
28					10/10	10/10	10/10	10/10
Nickel-plated Steel								
29	10/10	10/10	10/10	10/10	Failed			
30	10/10	10/10	10/10	10/10	Failed			
31	10/10	10/10	10/10	10/10	Failed			
32	10/10	10/10	10/10	10/10	Failed			
Phosphated Steel								
33	10/10	10/10	10/10	Failed				
34	10/10	10/10	10/10	Failed				
35	10/10	10/10	10/10	Failed				
36	10/10	10/10	10/10	Failed				

CORROSION RATES AT 70° F., 20% SODIUM CHLORIDE, pH 7.0

LENGTH OF TEST - 150 hours

VARIABLE - Temperature - 70° F.

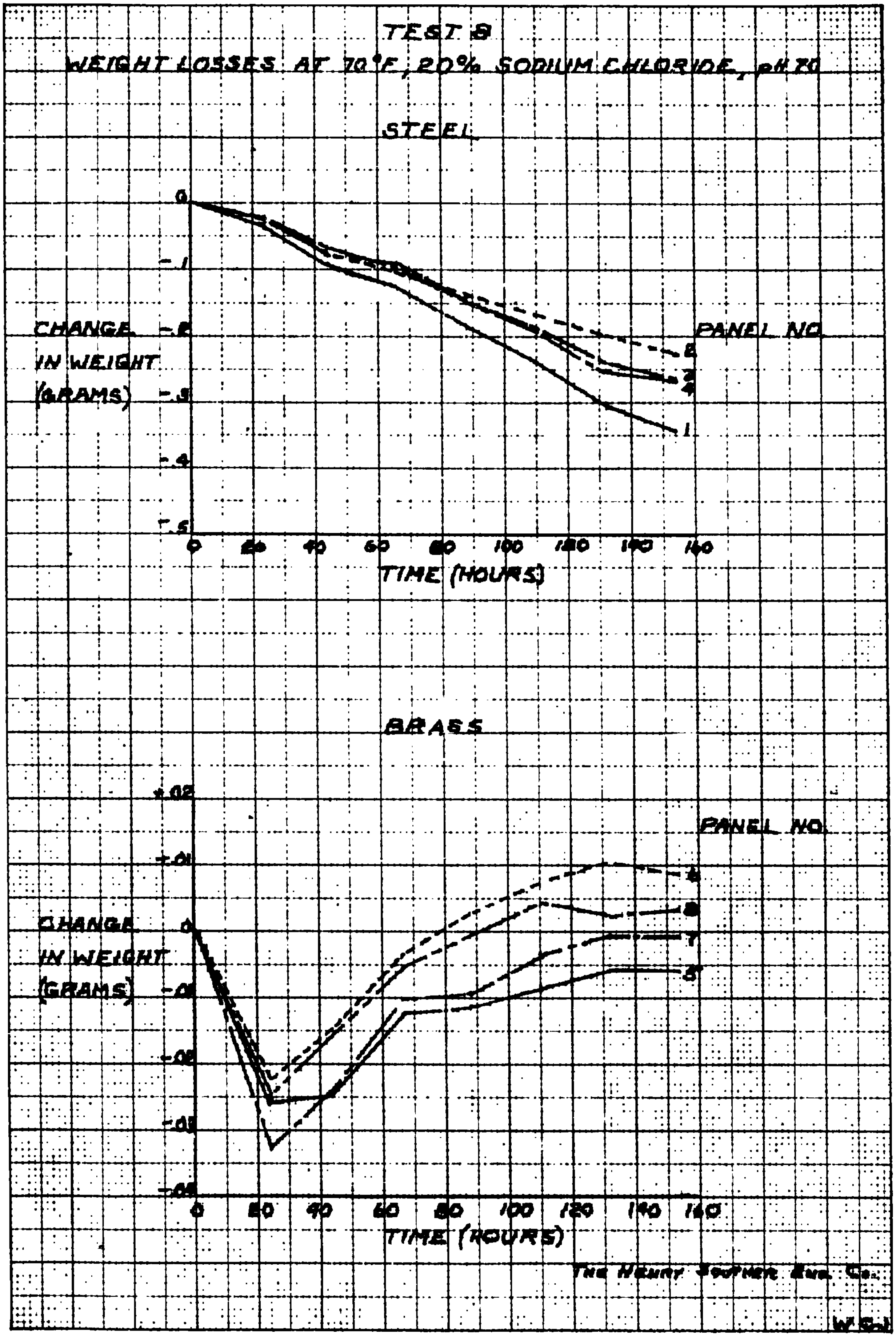
1/26/52 10% NaCl	1/27/52 20% NaCl	1/28/52 20% NaCl	1/29/52 20% NaCl	1/30/52 20% NaCl
[illegible]	70°	70°	70°	70°
70°	70°	70°	70°	70°
100%	100%	100%	100%	100%
.5	.5	.5	.5	.5
1×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}	2×10^{-6}
12	12	12	12	12
71°	71°	71°	71°	71°
.46	.46	.46	.46	.46
7.0	7.0	7.0	7.0	7.0
6.3	6.8	6.8	6.3	6.8
.9	.9	.9	.9	.9
99.8%	99.8%	99.8%	99.8%	99.8%
═══	═══	═══	═══	═══
1.150	1.150	1.150	1.150	1.150
5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0330	.0942	.1230	.1511	.2322	.3045	.3413
2					.0244	.0730	.1008	.1304	.1636	.1955	.2221
3					.0239	.0655	.0998	.1452	.1836	.2431	.2620
4					.0245	.0720	.0940	.1410	.1847	.2550	.2627
Brass											
5					.0258	.0247	.0127	.0111	.0061	.0060	.0060
6					.0221	.0144	.0036	-.0029	-.0071	-.0101	-.0093
7					.0323	.0244	.0102	.0094	.0035	.0006	.0008
8					.0240	.0154	.0057	.0006	-.0041	-.0023	-.0038
Zinc											
9					-.0310	.0186	-.0151	.0087	-.0142	-.0106	-.0081
10					.0472	.0153	-.0546	-.0091	-.0185	-.0272	-.0334
11					-.0039	.0257	-.0498	.0045	-.0320	-.0120	-.0476
12					-.0514	.0063	-.0614	-.0400	-.0333	-.0200	.0240
Cadmium											
13					.0482	.0980	.1331	.1828	.2297	.2684	.3066
14					.0320	.0907	.1331	.1538	.2382	.2763	.3251
15					.0381	.0911	.1328	.1756	.2267	.2565	.2845
16					.0323	.0941	.1335	.1789	.2234	.2532	.2531
Enamel											
17					10/10	10/10	10/10	10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
18					10/10	10/10	10/10	10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
19					10/10	10/10	10/10	10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
20					10/10	10/10	10/10	10/10	9.5/e/9.5	9.5/e/9.5	9.5/e/9.5
Anodized Aluminum (H_2SO_4)											
21					10/10	10/10	10/10	10/10	9/da/9	9.5/da/9	9.5/da/9
22					10/10	10/10	10/10	10/10	2.5/d/9	Failed	
23					10/10	10/10	10/10	10/10	6/d/9	2/dA/9	2/dA/9
24					10/10	10/10	10/10	10/10	3/d/9	3/d/9	3/d/9
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	10/10	9.5/a/9	9.5/a/9
26					10/10	10/10	10/10	10/10	10/10	9/a/9	9/a/9
27					10/10	6/a/7	6/a/7	6/a/7	6/a/7	5/a/7	5/a/7
28					10/10	10/10	10/10	10/10	9.5/d/9.5	4/d/9.5	4/d/9.5
Nickel-plated Steel											
29	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed						
31	10/10	10/10	10/10	10/10	Failed						
32	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel											
33	10/10	10/10	10/10	Failed							
34	10/10	10/10	10/10	Failed							
35	10/10	10/10	10/10	Failed							
36	10/10	10/10	10/10	Failed							

2

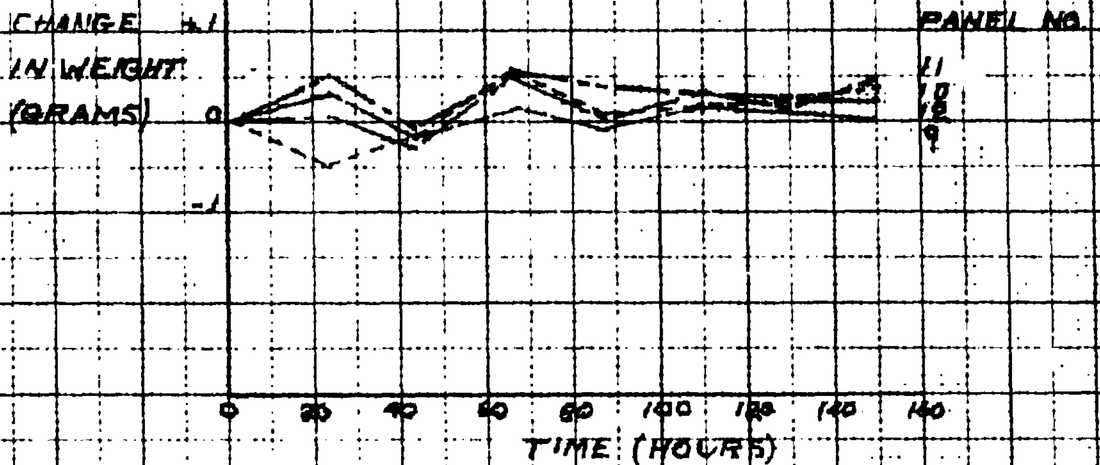
APPENDIX B


TEST 8
WEIGHT LOSSES AT 70°F, 20% SODIUM CHLORIDE, pH 7.0
STEEL
0
-.1
-.2
-.3
-.4
-.5
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
1
0
20
40
60
80
100
120
140
160
TIME (HOURS)
BRASS
+.02
+.01
0
-.01
-.02
-.03
-.04
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
8
7
5
0
20
40
60
80
100
120
140
160
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.

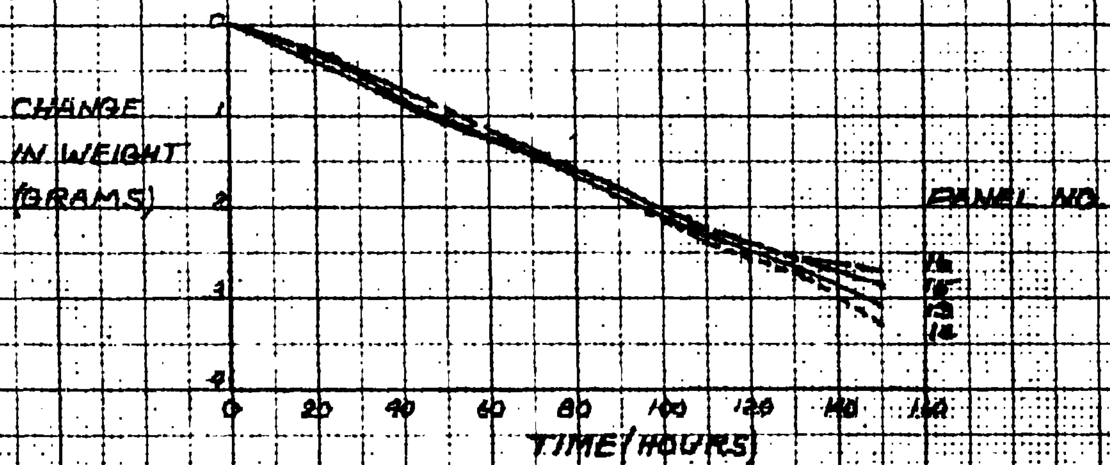
TEST 8

WEIGHT LOSSES AT 70°F, 20% SODIUM CHLORIDE, pH 7.0

ZINC



CADMIUM



THE HENRY SOUTHER ENG. CO.

W.S.-1

January 31, 1952

At the suggestion of Arthur Zavarella of Springfield Armory, we are going to add oxidized steel panels, prepared by Pentrating, to the series of specimens being tested in the salt spray cabinet. This is to be done because of the considerable use of oxidized steel for Ordnance.

Since the salt spray cabinet is being run on a total of thirty-six panels, and because the box has already been calibrated, using thirty-six panels with a random distribution which has not been changed, it seems desirable to eliminate one set of specimens. As the tests on the baked enamel panels are not significant in a 200-hr. test period, further test work on enameled panels is to be eliminated.

TEST NO. 9

Object

The object of this test is to determine the corrosive effects of a 20% sodium chloride solution, pH 7.0 at 90°F, on the nine materials described in Test No. 7.

Summary

A test has been conducted for a period of 150 hours in the salt spray test cabinet to determine the effect of decreasing the temperature 5°F below the standard value of 95°F. The concentration of the salt solution and its pH as well as the operating conditions of the box were maintained the same as in Test No. 7.

Introduction

This test, the fourth of the series, will be used along with the data from Tests Nos. 6, 7 and 8 to determine the effect of temperature variation on the rate of corrosion in a salt spray cabinet.

Procedure

A procedure similar to that outlined in Test No. 7 was followed and the test was run at 90°F with 20% sodium chloride solution, pH 7.0, for 150 hours. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprise Appendix B.

Discussion

The steel panels lost weight at a fairly consistent rate and the final order of their losses was the same as was previously experienced (i.e. 2, 3, 4, 1).

The brass panels, after an initial loss, gained weight but only two panels exceeded their original weight in contrast to the more general case where all the final weights exceed the original weights.

After some initial irregularities, the zinc panels lost weight steadily.

The cadmium panels lost constantly, and their weight losses were well grouped together.

The pentrated steel panels all failed before 1-1/2 hours, two failing before 1 hour.

The sulphuric acid anodized aluminum panels all failed before 22 hours, while the aluminum panels anodized by the chromic acid process failed before 129 hours exposure.

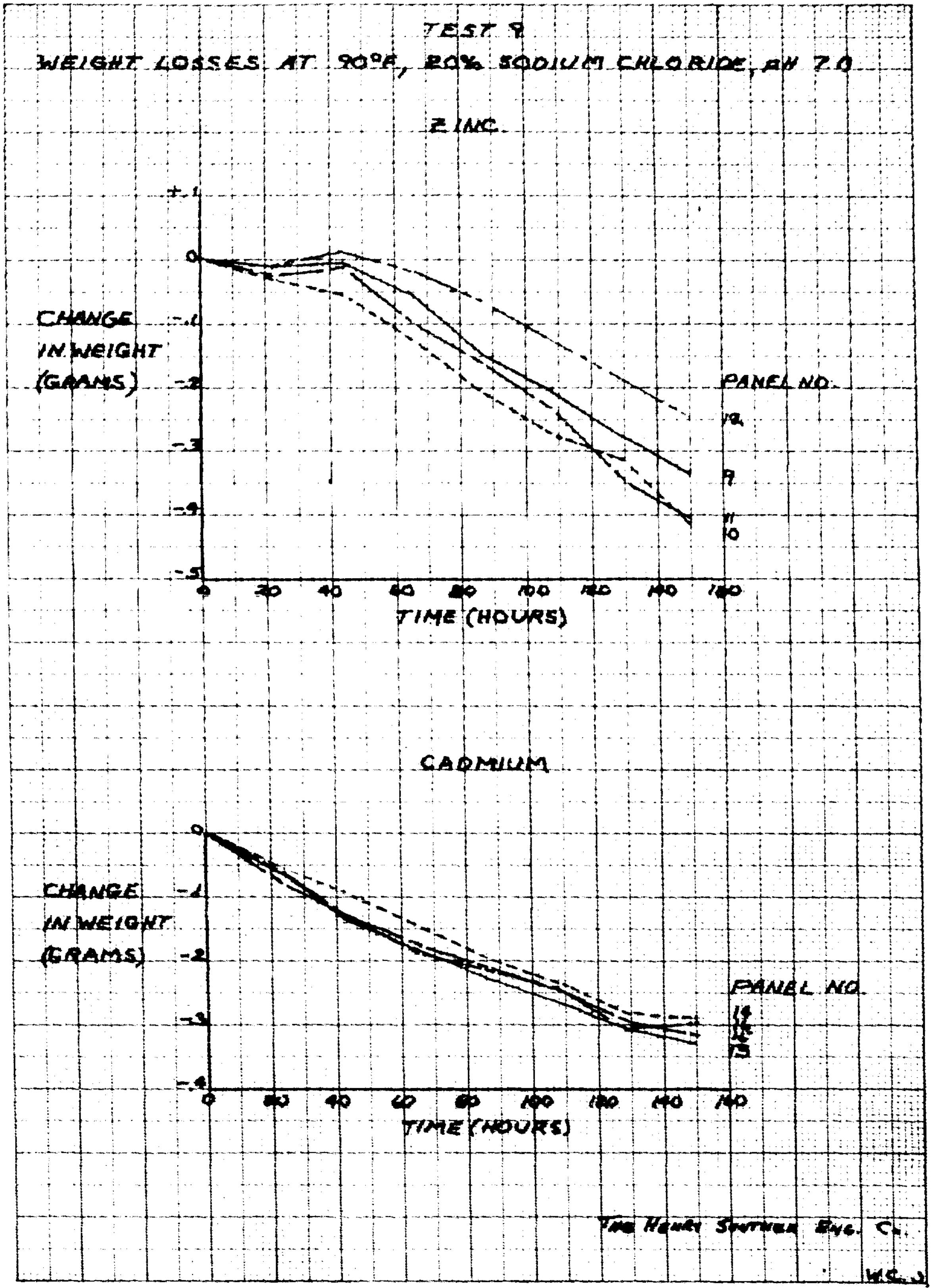
The nickel panels all failed before 1 hour, two failing before 1/2-hour.

The phosphated panels all failed before 2 hours exposure in the salt spray cabinet.

Conclusions

The data obtained in this run will be used in conjunction with those obtained on the three previous tests to determine the effect of temperature on the corrosion rate in the salt spray cabinet.

APPENDIX A


TEST 9
WEIGHT LOSSES AT 90°F, 20% SODIUM CHLORIDE, pH 7.0
ZINC
CHANGE IN WEIGHT (GRAMS)
+.1
0
-.1
-.2
-.3
-.4
-.5
PANEL NO.
12
9
11
10
0
20
40
60
80
100
120
140
160
TIME (HOURS)
CADMIUM
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
-.4
PANEL NO.
14
16
15
13
0
20
40
60
80
100
120
140
160
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.
W.C.

TEST NO. 10

Object

The object of this test is to determine the corrosive effects of a 10% sodium chloride solution, pH 7.0 at 95°F on steel, brass, zinc, cadmium, pentrated steel, chromic and sulphuric acid anodized aluminum, nickel plated steel and phosphated steel panels.

Summary

A test has been conducted for a period of 150 hours in the salt spray test cabinet to determine the effect of decreasing the concentration of salt in the salt spray solution from 20% to 10%. The temperature and pH of the solution were maintained the same as in Test No. 7.

Introduction

In any chemical or electrochemical reaction, the concentration of the reactants or electrolyte is of obvious importance. The concentration of salt in the salt solution used in this type of testing should, therefore, have a direct effect on the rate of corrosion. In this test and in Test No. 11, the concentration of salt will be reduced and its effect on the corrosion rate observed.

Procedure

A procedure similar to that described in Test No. 7 was followed. The test was run for 150 hours, using a 10% sodium chloride solution at pH 7.0. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A, and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight steadily and the brass panels, after initial losses, exceeded their original weight in three out of four cases.

The zinc and cadmium panels both lost weight in a manner similar to that previously experienced.

Three of the pentrated steel panels failed before 1/2-hour exposure, the other failing before 1 hour.

The aluminum panels anodized by the sulphuric acid process held up better than those prepared by the chromic acid process. The sulfuric acid anodized panels were little affected at the end of 150 hours exposure while three of the chromic acid anodized panels failed before 132 hours.

The nickel plated steel panels all failed before 24 hours exposure and the phosphated steel panels all failed before 1 hour.

Conclusions

These data form a measure of the corrosion rate at 95°F, using a 10% sodium chloride solution, pH 7.0. They will be used in conjunction with Tests No. 7 and No. 11 to determine the effect of salt concentration on the rate of corrosion.

APPENDIX A

TEST NUMBER 10

VARIABLE – CONCENTRATION – 10% SODIUM CHLORIDE

DATES	2/8/52	2/9/52	2/10/52	2/11/52	2/12/52	2/13/52	2/14/52
Solution Composition	10% NaCl	10% NaCl	10% NaCl	10% NaCl	10% NaCl	10% NaCl	10% NaCl
Dry Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (cm./sec.)	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}	2×10^{-5}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12
Air Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.48	.48	.48	.48	.48	.48	.48
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	1.3	1.1	1.1	.8	.9	.9	.9
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	——	——	——	——	——	——	——
3. Heavy Metals	——	——	——	——	——	——	——
Specific Gravity of Solution	1.078	1.078	1.078	1.078	1.078	1.078	1.078
Volume of Solution in Reservoir	6 gal.	6 gal.	6 gal.	5 gal.	6 gal.	6 gal.	6 gal.

CORROSION RATES AT 95° F., 10% SODIUM CHLORIDE, pH 7.0

LENGTH OF TEST – 150 hours

CUMULATIVE WEIGHT LOSSES (grams) and RAT NOS

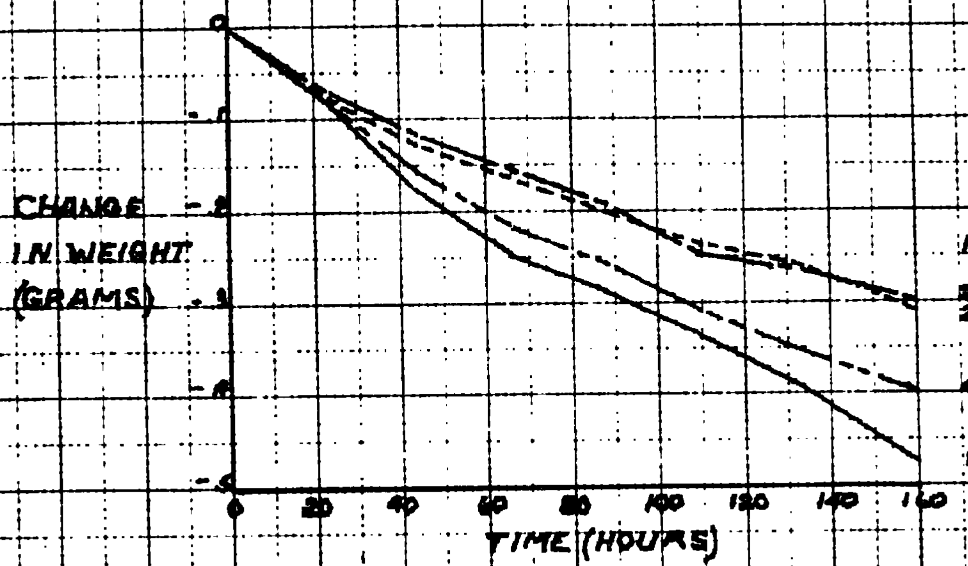
PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0563	.1783	.2457	.2574	.3381	.3967	.4777
2					.0795	.1254	.1610	.1901	.2344	.2549	.3078
3					.0711	.1150	.1574	.1908	.2431	.2614	.2958
4					.0855	.1565	.2157	.2517	.3094	.3434	.3928
Brass											
5					.0153	.0243	.0220	.0234	.0220	.0164	.0116
6					.0033	.0071	.0054	.0052	.0016	-.0006	-.0066
7					-.0034	.0015	-.0084	-.0108	-.0151	-.0211	-.0303
8					.0018	.0045	.0002	.0040	-.0017	-.0089	-.0065
Zinc											
9					.0293	.0595	.1513	.2117	.2948	.4222	.5226
10					.0434	.0936	.2550	.2697	.3696	.4678	.6254
11					.0406	.1197	.2232	.2782	.3734	.4659	.6188
12					.0349	.1066	.1967	.2621	.3471	[illegible]	.5768
Cadmium											
13					.0248	.0741	.1223	.1474	.1655	.2090	.2246
14					.0276	.0724	.1244	.1475	.1871	.2210	.2220
15					.0140	.0583	.1079	.1148	.1432	.1651	.2689
16					.0169	.0694	.1256	.1375	.1758	.1598	.1258
Penetrated Steel											
17	10/10	Failed									
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					9.5/a/9.5	9.5/a/9.5	9.5/a/9.5	9.5/a/9.5	9.5/a/9.5/	9.5/a/9.5	9.5/a/9.5
22					10/10	10/10	10/10	10/10	10/10	10/10	[illegible]
23					10/10	10/10	10/10	10/10	10/10	10/10	10/10
24					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	10/10	10/10	10/10
26					10/10	10/10	10/10	[illegible]	4/d/9	Failed	
27					10/10	10/10	10/10	6/d/9	Failed		
28					10/10	10/10	10/10	1/d/9	Failed		
Nickel-plated Steel											
29	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed						
31	10/10	10/10	10/10	10/10	Failed						
32	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel											
33	10/10	Failed									
34	10/10	Failed									
35	10/10	Failed									
36	10/10	Failed									

APPENDIX B

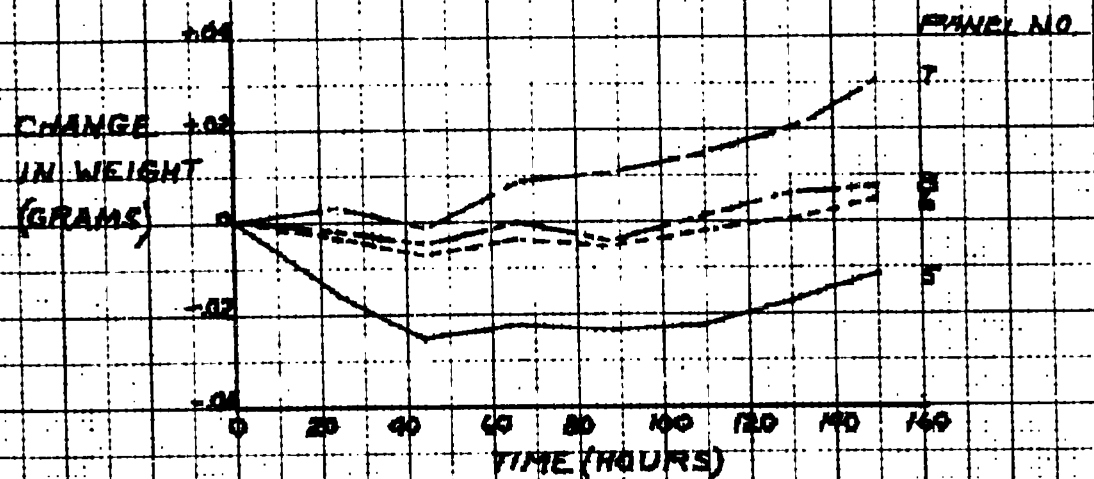
TEST 10

WEIGHT LOSSES AT 95°F, 10% SODIUM CHLORIDE, pH 7.0

STEEL



BRASS

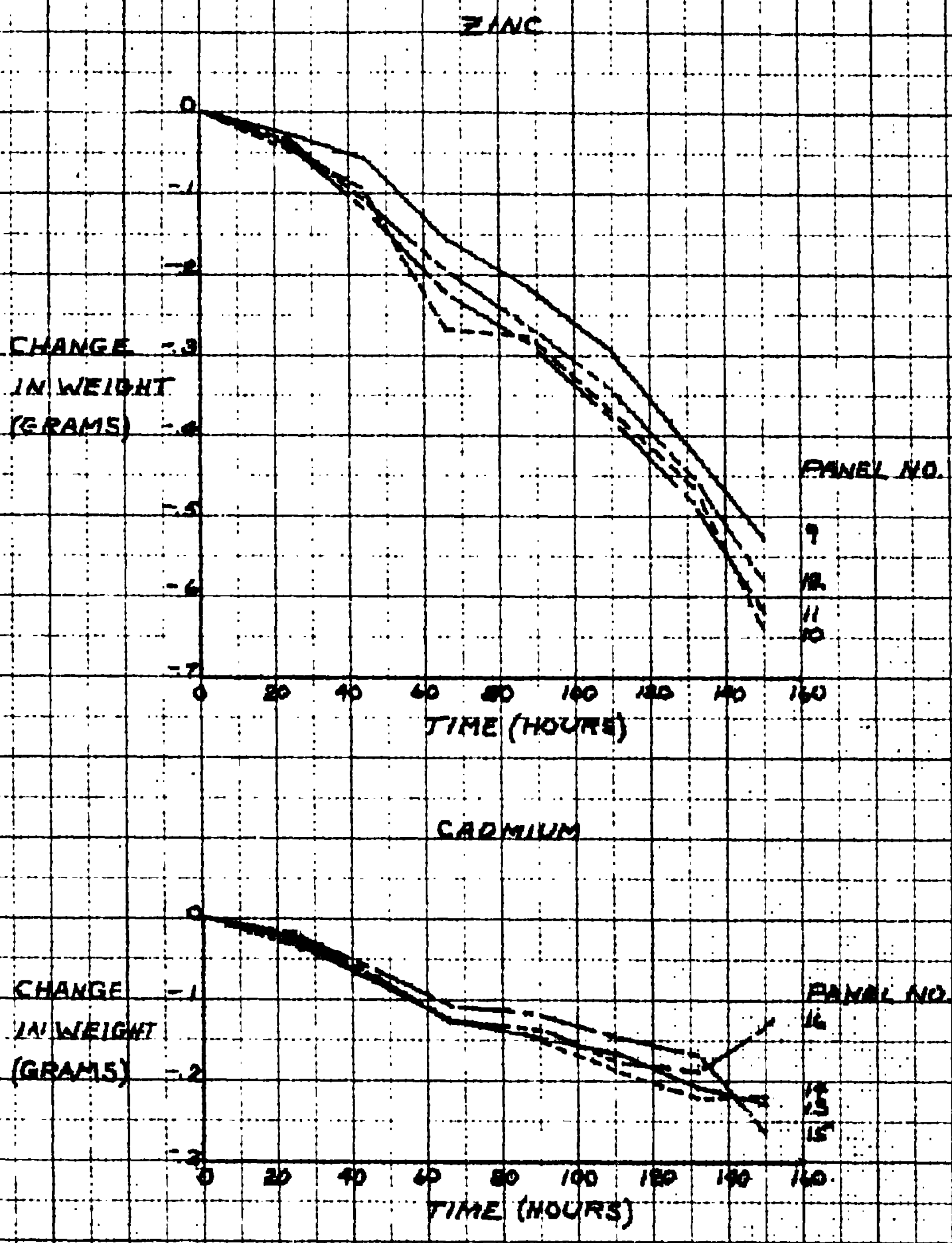


THE HENRY SOUTHER ENG. CO.

WCJ

TEST 10

WEIGHT LOSSES AT 95°F, 10% SODIUM CHLORIDE, pH 7.0



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TEST NO. 11

Object

The object of this test is to determine the corrosive effects of a 5% sodium chloride solution, pH 7.0 at 95°F, on the nine materials listed in Test No. 10.

Summary

A test has been conducted for a period of 150 hours in the salt spray test cabinet to determine the effect of decreasing the concentration of salt in the solution from 20% to 5%. The temperature and pH were maintained the same as in Test No. 7.

Introduction

This test represents the lowest limit of salt concentration and will be used in conjunction with Tests No. 7 and No. 10 to determine the effect of concentration of salt in the solution on the rate of corrosion in the salt spray test cabinet.

Procedure

A procedure similar to that described in Test No. 7 was followed. The test was run for 150 hours, using a 5% sodium chloride solution at pH 7.0. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a fairly steady rate with Panel No. 1 still showing the greatest loss that has been experienced on all previous tests of this type.

The brass panels showed no initial loss and gained weight steadily, while the zinc and cadmium panels lost in the previously experienced manner.

The pentrated steel panels all showed rust at the end of 1/2-hour's exposure.

The aluminum panels anodized by the sulphuric acid process showed a superiority over those prepared by the chromic acid process. Three of the sulphuric acid anodized panels showed no signs of corrosion after 150 hours exposure, while all of the chromic acid anodized panels showed evidence of attack after 110 hours.

The nickel plated steel panels all failed before 24 hours exposure, and the phosphated steel panels all failed before 2 hours.

Conclusions

These data constitute a measure of the corrosion rate at 95°F. 5% sodium chloride, pH 7.0. These results will be used to determine the effect of concentration of salt in the solution on the rate of salt spray corrosion.

APPENDIX A

TEST NUMBER 11

DATA TABLE – Concentration – 5% Sodium Chloride

DATE	2/15/52 5% NaCl	2/15/52 5% NaCl	2/17/52 5% NaCl	2/[illegible]/52 5% NaCl	2/19/52 5% NaCl	2/20/52 5% NaCl	2/21/52 5% NaCl
Solution Composition							
Dry Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100	100%	100%	100	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (m./sec.)	6×10^{-5}	6×10^{-5}	6×10^{-5}	6×10^{-5}	6×10^{-5}	6×10^{-5}	6×10^{-5}
Air Pressure (lbs./in.^{2})	11.5	11.6	11.5	11.6	11.5	11.5	11.5
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/sec.)	.49	.49	.49	.48	.49	.49	.49
pH of Solution	7.0	7.[illegible]	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (ls./hr.)	1.2	1.5	1.2	.7	1.3	1.0	1.0
Impurities in Salt Solution							
1. Assay	99.0%	99.3%	99.8%	99.4%	99.8%	99.3%	99.8%
2. Br and I	———	———	———	———	———	———	———
3. Heavy Metals	———	———	———	———	———	———	———
Specific Gravity of Solution	1.037	1.037	1.037	1.037	1.037	1.037	1.037
Volume of Solution in Reservoir	5 gal.	7 gal.	5 gal.	5 gal.	5 gal.	4 gal.	4 gal.

CORROSION RATES AT 95° F., 5% SODIUM CHLORIDE, pH 7.0

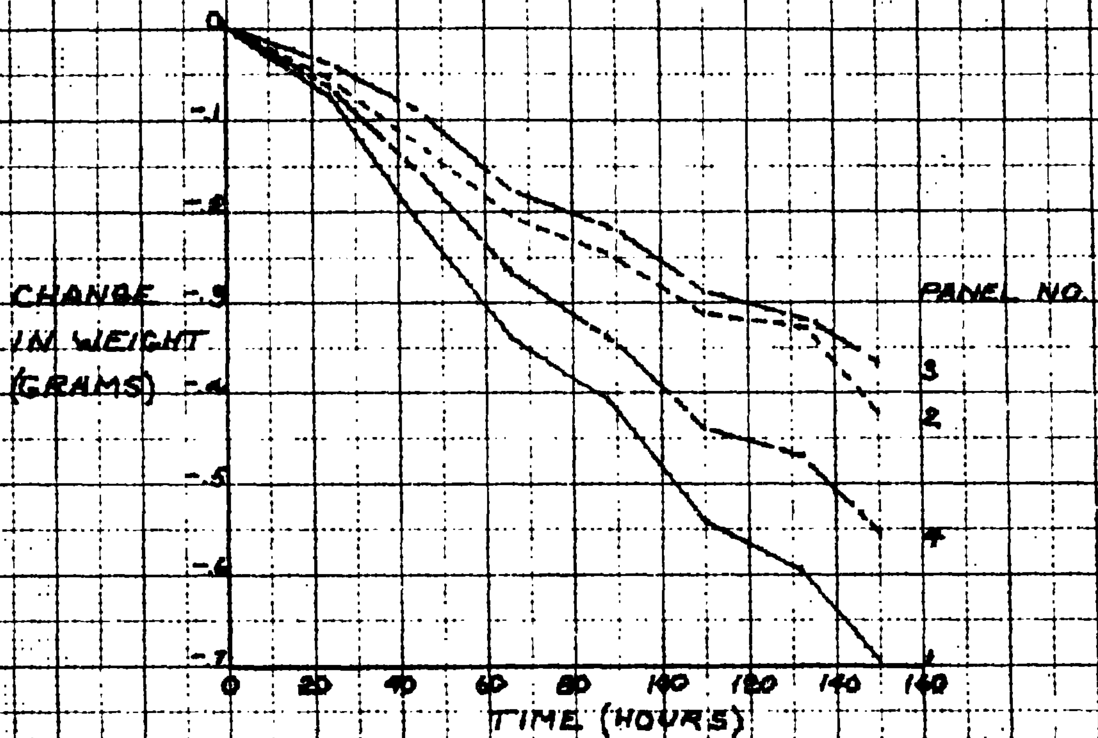
LENGTH OF TEST – 150 hours

PANEL NO.	1/2 hr.	1 hr.	1 1/2 hrs.	2 hrs.	21 hrs.	44 hrs.	66 hrs.	84 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0734	.2025	.3377	.4047	.5435	.5924	.6988
2					.0513	.1232	.2051	.2432	.3104	.3215	.4149
3					.0535	.0926	.1756	.2140	.2860	.3194	.3673
4					.0632	.1504	.2694	.3342	.4563	.4580	.5524
Brass											
5					-.0070	-.0110	-.0130	-.0134	-.0165	-.0232	-.0245
6					-.0075	-.0129	-.1168	-.0259	-.0229	-.0256	-.0249
7					-.0034	-.0107	-.0162	-.0191	-.0223	-.0249	-.0287
8					-.0025	-.0129	-.0160	-.0207	-.0257	-.0279	-.0302
Zinc											
9					.0591	.1097	.1990	.2295	.2970	.3150	.5935
10					.1120	.2221	.3500	.4153	.4929	.5565	.2552
11					.0185	.1240	.2524	.2013	.3959	.4539	.5780
12					.0323	.1116	.1968	.2356	.7126	.3237	.4112
Cadmium											
13					-.0025	.0535	.0940	.1207	.1474	.1681	.1915
14					-.0007	.0814	.0971	.1230	.1431	.1757	.1821
15					-.0025	.0750	.1134	.1435	.1773	.1934	.2230
16					.0008	.0627	.0974	.1234	.1560	.1375	.2032
P[illegible]ated Steel											
17	Failed										
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					10/10	10/10	10/10	10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10	10/10	10/10	10/10
23					10/10	10/10	10/10	10/10	10/10	10/10	10/10
24					7/a/9	7/a/9	7/a/9	Failed			
Anodized Aluminum											
25					10/10	10/10	10/10	10/10	10/10	8/d/9	8/d/9
26					10/10	10/10	10/10	10/10	10/10	1/d/9	Failed
27					10/10	10/10	10/10	Failed			
28					10/10	10/10	10/10	1/d/9	Failed		
Nickel-plated Steel											
29	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed						
31	10/10	10/10	10/10	10/10	Failed						
32	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel											
33	10/10	10/10	Failed								
34	10/10	10/10	10/10	Failed							
35	10/10	10/10	Failed								
36	10/10	10/10	Failed								

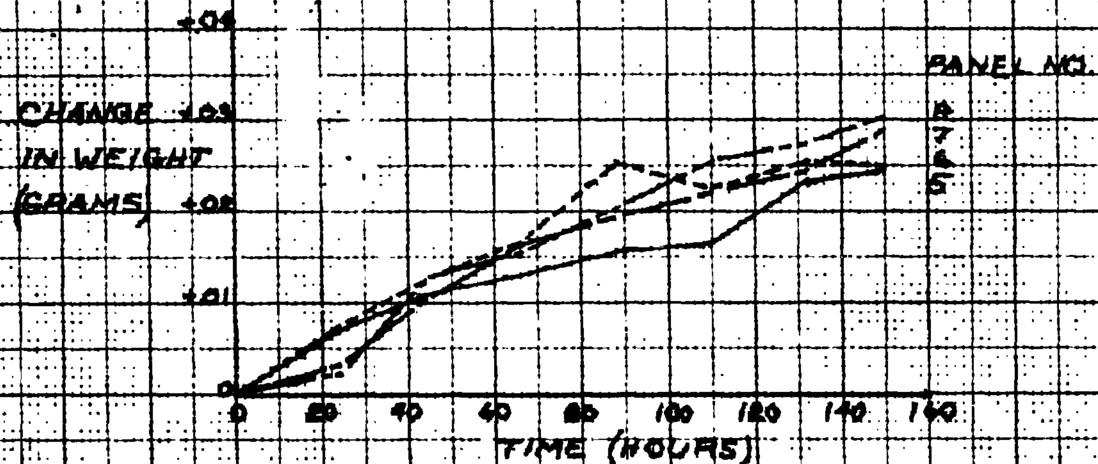
APPENDIX B

TEST 11
WEIGHT LOSSES AT 95°F, 5% SODIUM CHLORIDE, pH 7.0

STEEL



BRASS



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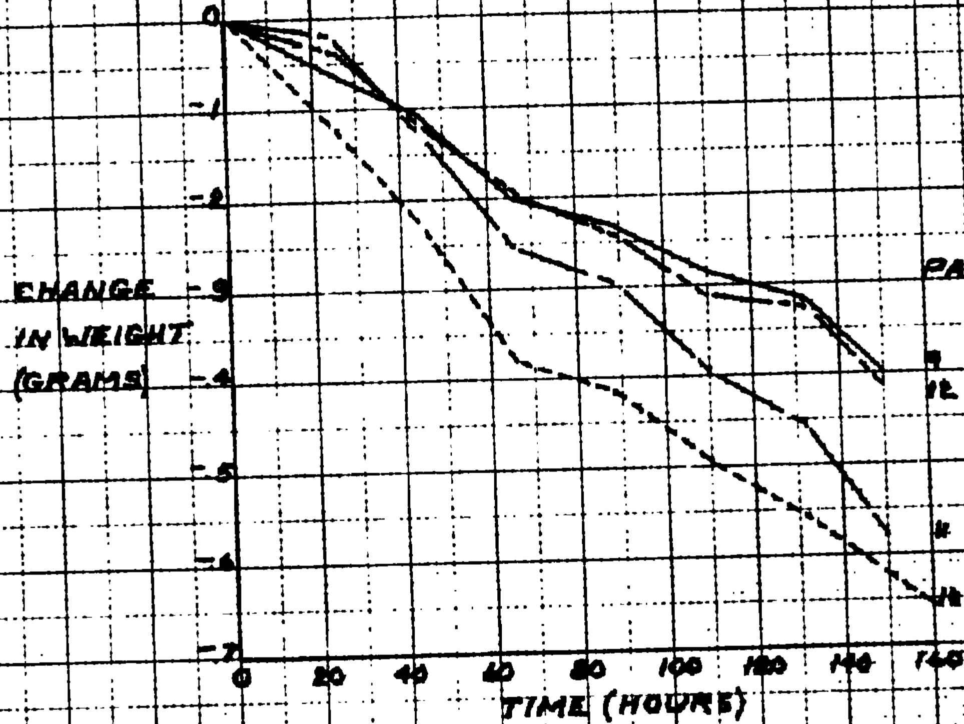
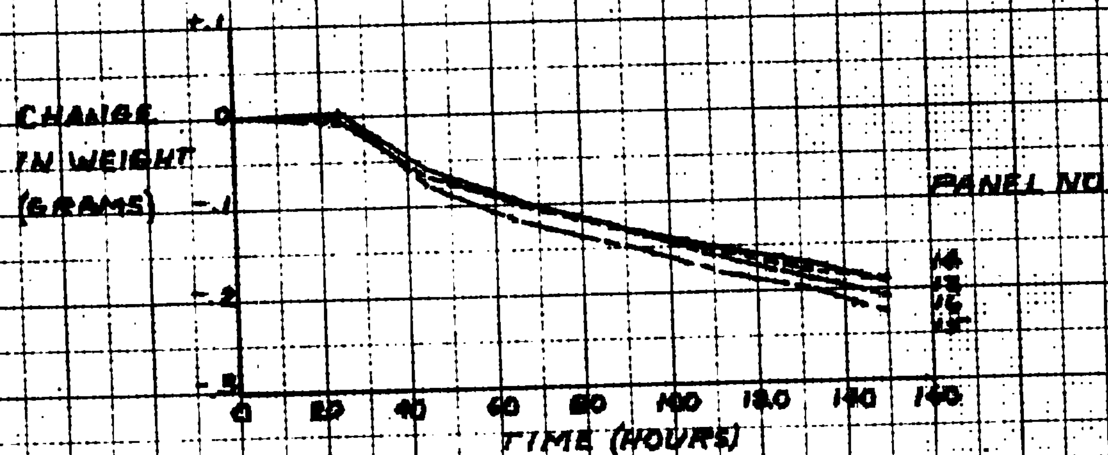
TEST 11

WEIGHT LOSSES AT 95°F, 5% SODIUM CHLORIDE, pH 7.0

ZINC



CADMIUM



THE HENRY SOUTHER ENG. CO.

W.G.J.

TEST NO. 12

Object

The object of this test is to determine the corrosive effects of a 5% sodium chloride solution, pH 7.0 at 70°F on the various types of panels used in this series of tests.

Summary

A test has been conducted in the salt spray test cabinet at 70°F, using a 5% sodium chloride solution, pH 7.0.

Introduction

The information collected in this test, the last of a series, will be used together with the results from Tests 6 through 11 to determine the effect of concentration of salt solution and temperature of operation on the corrosion rate. This test represents the lower limits of temperature and concentration that will be used for comparison.

Procedure

A procedure similar to that described in Test No. 7 was followed. The test was run for 150 hours, using a 5% sodium chloride solution at pH 7.0. The temperature of the box was maintained at 70°F. The cumulative weight losses, panel ratings and operating conditions are tabulated in Appendix A and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a reasonably steady rate and the order of their weight losses was the same as has been previously experienced.

The brass panels showed no initial loss in weight and, with minor variations, gain weight consistently.

The zinc panels did not show their usual steady loss in weight, but instead, after initial losses, tended to approach a steady weight value.

The cadmium panels lost weight at a consistent rate, and the values were closely grouped as usual.

The pentrated panels all failed before 1 hour's exposure, while both the sulfuric acid and chromic acid anodized aluminum panels showed very little evidence of attack at the end of the test period of 150 hours.

The nickel plated steel panels all failed before 24 hours, and the phosphated panels failed before 2 hours.

Conclusions

These data constitute a measure of the corrosion rate at 70°F, using 5% salt, pH 7.0. The information will be used in comparisons with previous tests to determine the effect of temperature and concentration on the corrosion rate.

TEST NUMBER 18

CORROSION RATES AT 70° F., 5% SODIUM CHLORIDE, pH 7.0

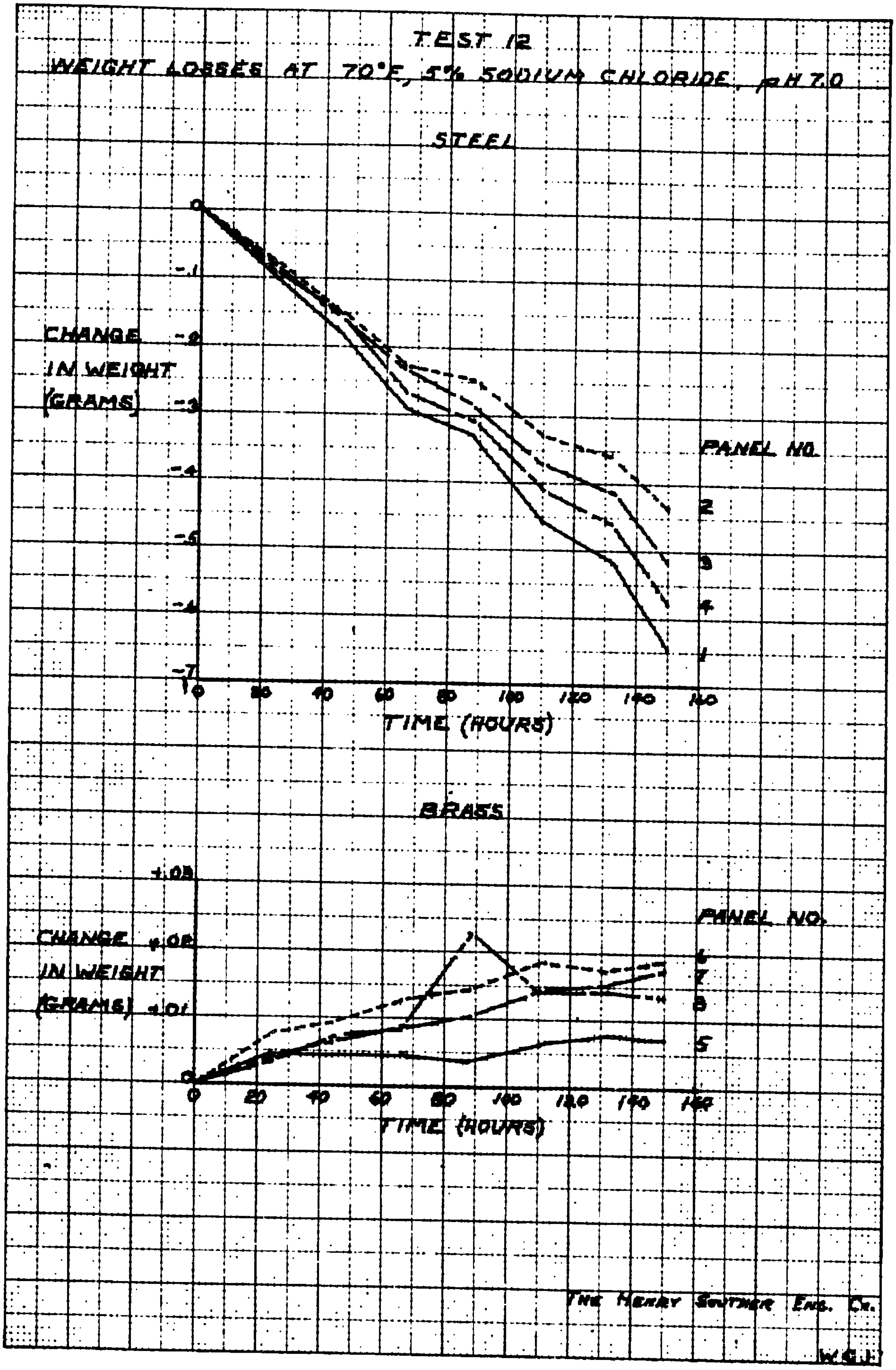
LENGTH OF TEST – 150 hours

DATES	2/22/52	2/23/52	2/24/52	2/25/52	2/26/52	2/27/52	2/28/52
Solution Composition	5% NaCl	5% NaCl	5% NaCl	5% NaCl	5% NaCl	5% NaCl	5% NaCl
Dry Bulb Temp. (° F.)	70°	70°	7 °	70°	70°	70°	70°
Wet Bulb Temp. (° F.)	70°	70°	70°	70°	70°	70°	70°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.	.5	.5
Rate of Settling (mm./sec.)	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	71°	71°	71°	71°	71°	71°	71°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.46	.46
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	1.5	1.3	1.2	1.2	1.2	1.2	1.2
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	——	——	——	——	——	——	——
3. Heavy Metals	——	——	——	——	——	——	——
Specific Gravity of Solution	1.037	1.037	1.037	1.037	1.037	1.037	1.037
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

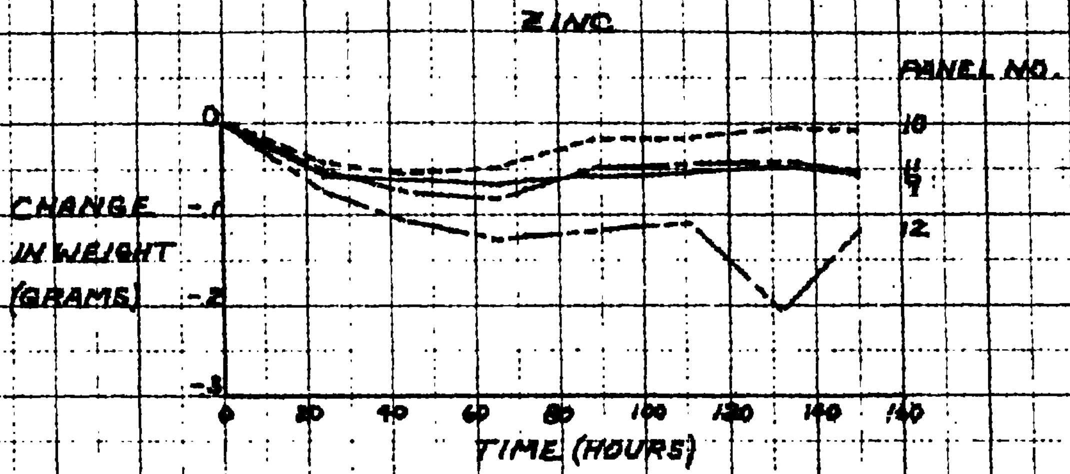
PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0371	.1719	.2907	.3296	.4449	.5152	.6458
2					.0757	.1418	.2230	.2448	.3277	.3533	.4380
3					.0787	.1808	.2314	.2927	.3705	.4128	.5191
4					.0942	.1428	.2622	.3051	.4101	.4588	.5767
Brass											
5					-.0046	-.0047	-.0045	-.0038	-.0053	-.0078	-.0071
6					-.0074	-.0101	-.0127	-.0146	-.0152	-.0172	-.0190
7					-.0035	-.0071	-.0094	-.0135	-.0143	-.0161	-.0178
8					-.0041	-.0054	-.0068	-.0228	-.0141	-.0146	-.0135
Zinc											
9					.0582	.0601	.0569	.0580	.0624	.0461	.0584
10					.0400	.0522	.0470	.0170	.0125	.0044	.0064
11					.0569	.0715	.0310	.0497	.0414	.0436	.0503
12					.0702	.1049	.12 8	.1179	.1095	.2059	.1178
Cadmium											
13					.0457	.0701	.0964	.1241	.1456	.1696	.1978
14					.0535	.0693	.0947	.1182	.1465	.1700	.1856
15					.0495	.0851	.1146	.1415	.1673	.1906	.2015
16					.0572	.0463	.1129	.1565	.1900	.1905	.2336
Pentrated Steel											
17	10/10	Failed									
18	Failed										
19	10/10	Failed									
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					10/10	10/10	10/10	10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10	10/10	10/10	10/10
23					10/10	10/10	10/10	10/10	10/10	10/10	10/10
24					10/10	10/10	10/10	10/10	10/10	10/10	6.8/d/9
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	10/10	10/10	10/10
26					10/10	10/10	10/10	10/10	10/10	10/10	10/10
27					10/10	10/10	10/10	10/10	10/10	10/10	10/10
28					10/10	10/10	10/10	10/10	10/10	7/d/9	6/d/9
Nickel-plated Steel											
29	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	Failed							
31	10/10	10/10	10/10	10/10	Failed						
32	10/10	10/10	10/10	Failed							
Phosphated Steel											
33	10/10	10/10	10/10	Failed							
34	10/10	10/10	10/10	Failed							
35	10/10	10/10	10/10	Failed							
36	10/10	10/10	10/10	Failed							

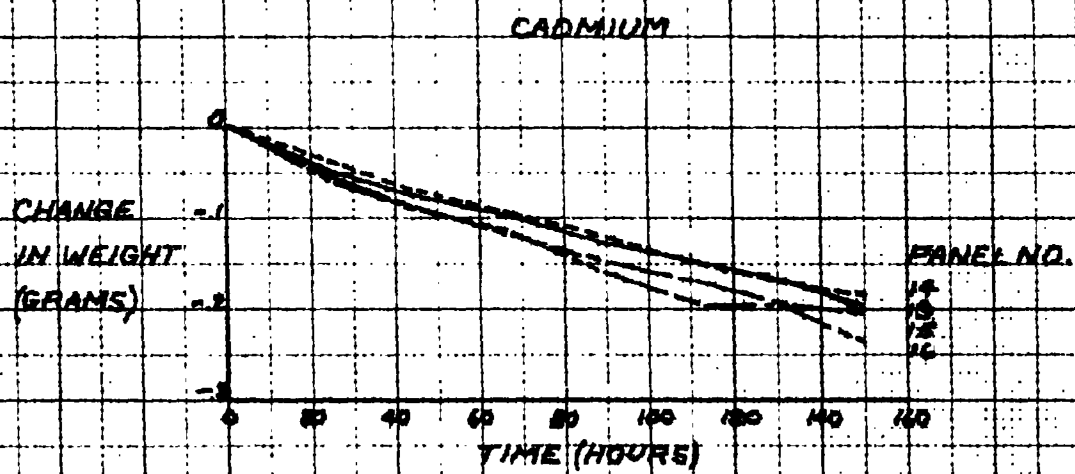
APPENDIX B


TEST 12
WEIGHT LOSSES AT 70°F, 5% SODIUM CHLORIDE, pH 7.0
STEEL
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
PANEL NO.
2
3
4
1
0
20
40
60
80
100
120
140
160
TIME (HOURS)
BRASS
CHANGE IN WEIGHT (GRAMS)
+.03
+.02
+.01
0
PANEL NO.
6
7
8
5
0
20
40
60
80
100
120
140
160
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.
W.G.J.

TEST 12

WEIGHT LOSSES AT 70°F, 5% SODIUM CHLORIDE, pH 7.0





The Henry Souther Eng. Co.

W.C.M.

TEST NO. 13

Object

The object of this test is to determine the corrosive effects of a 20% sodium chloride solution, pH 6.0 at 95°F, on the various types of panels used in the previous tests.

Summary

A test has been conducted in the salt spray cabinet at 95°F, using a 20% salt solution with a pH of 6.0 as compared with 7.0 used heretofore.

Introduction

The pH and hence the acidity or alkalinity of the salt spray solution should have a direct bearing on the rate of corrosion in the test cabinet. This test at pH 6.0, together with the data to be obtained in Test No. 14 at pH 8.0, will be used in comparison with Test No. 7 to determine the effect of pH on the corrosion rate.

Procedure

A procedure similar to that described in Test No. 7 was followed. The test was run for 150 hours, using a 20% sodium chloride solution at pH 6.0. The temperature of the box was maintained at 95°F. The cumulative weight losses, panel ratings and a summary of the operating conditions are tabulated in Appendix A, and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost at a reasonably consistent rate, while the brass panels showed wide variations and unusually high gains in weight.

The zinc panels lost at a fairly steady rate, the weight losses being greater than those usually experienced.

The cadmium panels lost weight at an even rate in a manner similar to that previously experienced.

The pentrated panels all failed before one-half hour's exposure.

The chromic acid anodized aluminum panels proved superior to those prepared by the sulfuric acid process. All the sulfuric acid panels showed signs of attack at 24 hours, while no appreciable signs of corrosion appeared on the chromic acid panels until 88 hours.

The nickel plated steel panels all failed before 2 hours, and the phosphated steel panels all failed before 1-1/2 hours.

<u>Conclusions</u>

The data collected in this run constitute a measure of the corrosion rate at 95°F with 20% salt solution, pH 6.0, and will be used to determine the effect of pH variation on the rate of corrosion in the salt spray cabinet.

APPENDIX A

TEST NUMBER 13

[illegible] AT 95° F., 20% [illegible], pH 6.0

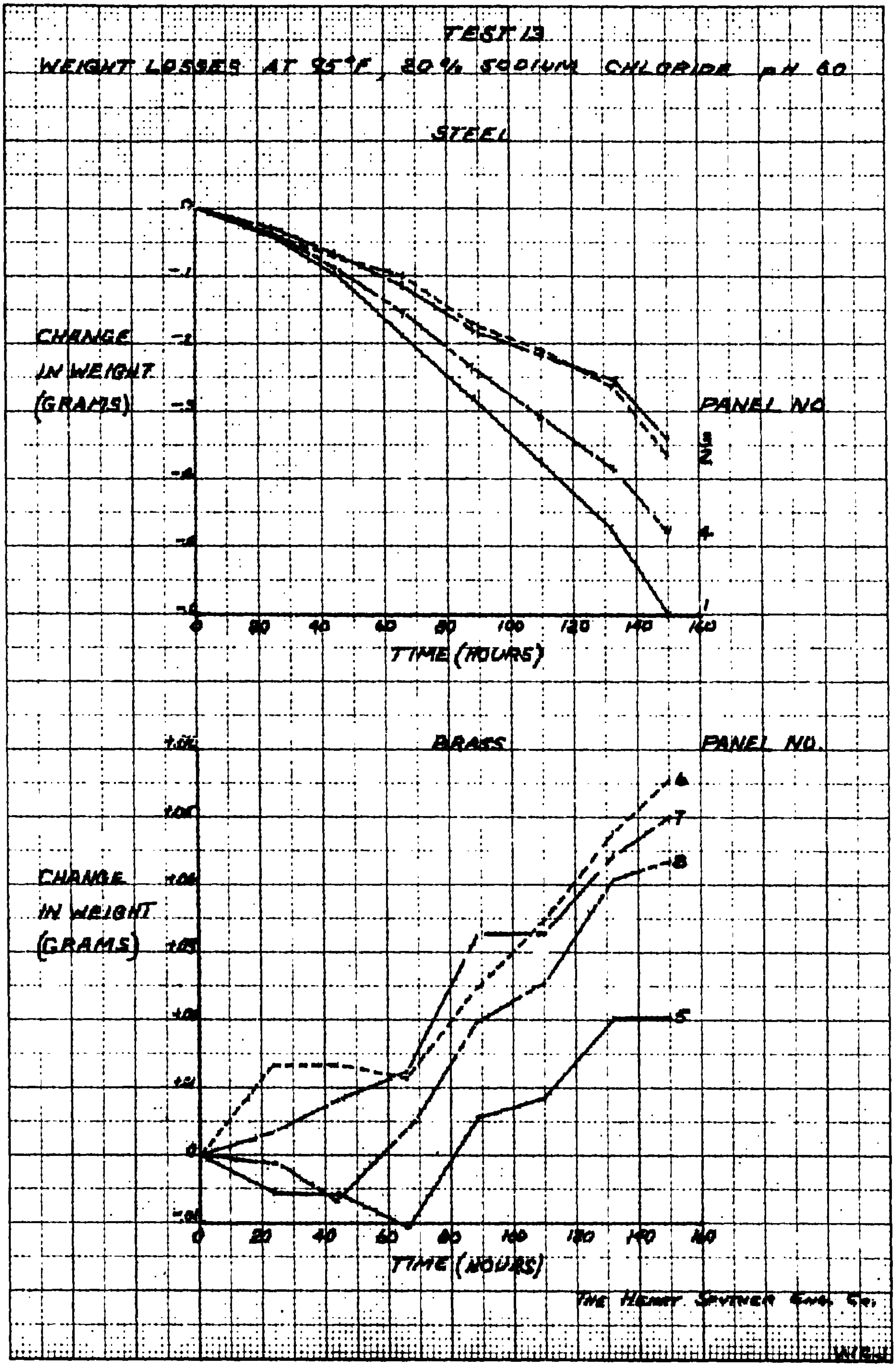
DATES	3/29/52	3/[illegible]/52	3/[illegible]/52	3/3/52	3/4/52	3/[illegible]/52	3/6/52
				[illegible] pH 6.0			
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size(microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (m./sec.)	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	93°	93°	93°	93°	93°	93°	93°
Rate of Flow (ft.^{3}/min.)	.46	.48	.48	.46	.46	.45	.46
pH of Solution	6.0	6.0	6.0	6.0	6.0	6.0	6.0
pH of Fog	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Rate of Fog Collection (mls./hr.)	1.2	.9	1.2	1.[illegible]	1.1	1.3	1.4
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	———	———	———	———	———	———	———
3. Heavy metals	———	———	———	———	———	———	———
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	6 gal.	6 gal.	[illegible]	[illegible] gal.	[illegible]	6 gal.	6 gal.

LENGTH OF TEST - 150 hours

[illegible] WEIGHT LOSS (grams) and [illegible]

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	48 hrs.	65 hrs.	85 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0407	.0956	.1919	.2[illegible]39	.3776	.4695	.6001
2					.0346	.0653	.0[illegible]92	.1561	.2108	.2549	.3514
3					.0241	.0326	.1036	.1698	.2154	.2547	.3469
4					.0421	.0650	.1496	.2[illegible]	.3061	.3[illegible]07	.4786
Brass											
5					.0055	.0062	.0112	-.0059	-.0084	-.0208	-.0287
6					-.0133	-.0134	-.0115	-.0247	-.0349	-.0479	-.0558
7					-.0058	-.0081	-.0125	-.0321	-.0329	-.0447	-.0498
8					.0010	.0067	-.0030	-.0195	-.0258	-.0408	-.0436
Zinc											
9					.0555	.1464	.2312	.2579	.3764	.4807	.6032
10					.0921	.1575	.3428	.4134	.5095	.7305	.7908
11					.0613	.1366	.2718	.3139	.5071	.5488	.7611
12					.1124	.1332	.2308	.2481	.3653	.5219	.6624
Cadmium											
13					.0235	.0533	.0[illegible]71	.1297	.1501	.1504	.2055
14					.0323	.0874	.1107	.1160	.1[illegible]13	.2201	.2138
15					.0321	.0637	.0365	.1335	.1532	.1739	.1999
16					.0370	.0773	.1041	.1317	.1701	2065	.2073
Pentrated teel											
17	Failed										
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					Failed						
22					[illegible]/ds/9	[illegible]/ts/9	3.5/ds/9	Failed			
23					[illegible].5/x/9	2/s/9	1.5/s/9	Failed			
24					[illegible]/ds/9	6.5/ds/9	5.5/ds/9	Failed			
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	2.5/d/9	Failed	
26					10/10	10/10	9.5/d/9	Failed			
27					10/10	10/10	10/10	10/10	[illegible].5/d/9	Failed	
28					10/10	10/10	10/10	3.5/d/9	2.5/d/9	Failed	
Nickel-plated Steel											
29	10/10	10/10	Failed								
30	10/10	10/10	Failed								
31	10/10	10/10	Failed								
32	10/10	10/10	10/10	Failed							
Phosphated Steel											
33	10/10	10/10	Failed								
34	10/10	10/10	Failed								
35	10/10	10/10	Failed								
36	10/10	10/10	Failed								

APPENDIX B



TEST 13
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE pH 6.0
STEEL
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
TIME (HOURS)
0 20 40 60 80 100 120 140 160
BRASS
PANEL NO.
CHANGE IN WEIGHT (GRAMS)
6
7
8
5
TIME (HOURS)
0 20 40 60 80 100 120 140 160
THE HENRY SOUTHER ENG. CO.

TEST NO. 14

Object

The object of this test is to determine the corrosive effects of a 20% sodium chloride solution, pH 8.0 at 95°F, on the various types of panels used in previous tests.

Summary

A test has been conducted in the salt spray cabinet at 95°F, using a 20% sodium chloride solution adjusted to pH 8.0.

Introduction

This test, the third of a series, will be used to supply additional information as to the effect of a change in pH on the rate of corrosion.

Procedure

A procedure similar to that described in Test No. 7 was followed. The test was run for 150 hours, using a 20% sodium chloride solution adjusted to pH 8.0. The temperature of the box was maintained at 95°F. The cumulative weight losses, panel ratings and a summary of the operating conditions are tabulated in Appendix A, and a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight steadily and in about the manner usually experienced. The brass panels, after an initial loss, gained weight although the time necessary to exceed their original weight varied widely.

The zinc panels showed high weight losses when compared with the values usually obtained. The cadmium panels lost weight, although the rate was not as constant as usual.

The pentrated steel panels all failed before 1/2 hour. Wide variations were experienced in the time for failure of the anodized aluminum panels; two of those prepared by the sulfuric acid process failing before 24 hours exposure. The chromic acid anodized aluminum panels failed in between 66 to 110 hours exposure.

The nickel plated steel panels all failed before 2 hours as did the phosphated steel panels.

Conclusions

The values collected in this test will be used as a measure of the corrosion rate at 95°F, using a 20% salt solution, pH 8.0, and will be used in comparison with the results from Tests No. 12 and No. 7 to determine the effect of pH on the corrosion rate.

APPENDIX A

TEST NUMBER 14

VARIABLE - pH 8.0

DATES	3/7/52	3/8/52	3/9/52	3/10/52	3/11/52	3/12/52	3/13/52
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (mm./sec.)	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.46	.46
pH of Solution	8.0	8.0	8.0	8.0	8.0	8.0	8.0
pH of Fog	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Rate of Fog Collection (mls./hr.)	.7	.9	.7	1.1	1.1	1.2	1.1
Impurities in Salt Solution							
1. Assay	99.8%	99.9%	99.8%	99.8%	99.9%	99.8%	99.8%
2. Br and I	———	———	———	———	———	———	———
3. Heavy metals	———	———	———	———	———	———	———
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 8.0

LENGTH OF TEST - 150 hours

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

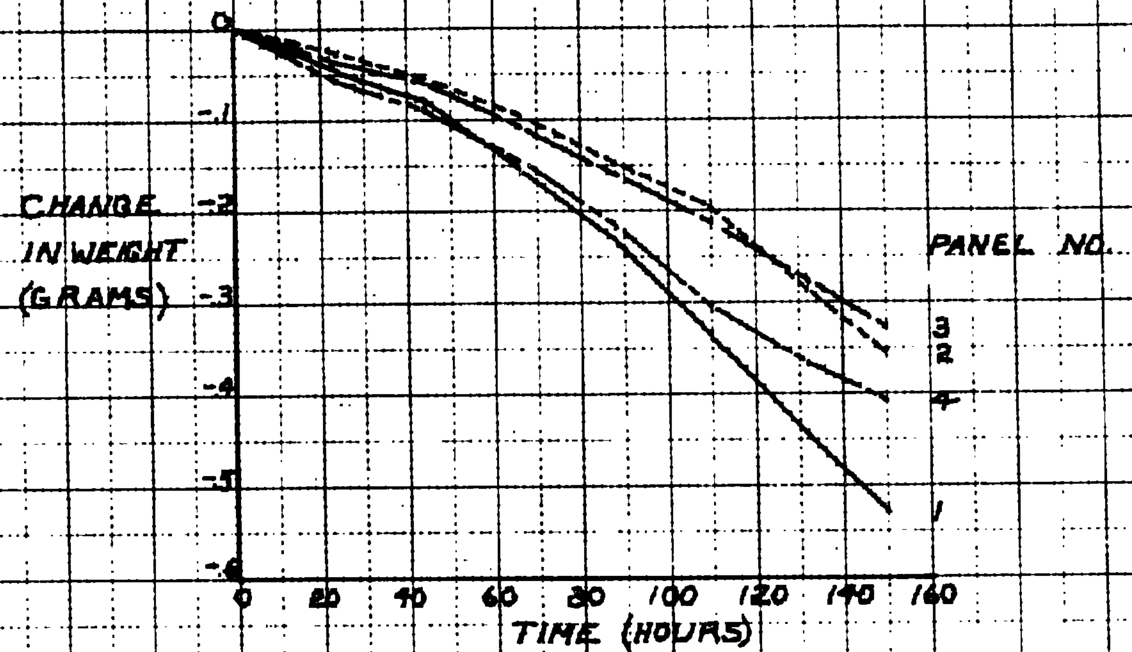
PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0463	.0791	.1532	.2505	.3386	.4445	.5234
2					.0260	.0582	.0947	.1447	.1954	.2535	.3509
3					.0336	.0691	.1382	.1634	.2109	.2760	.3259
4					.0550	.0872	.1427	.2165	.3050	.3639	.4062
Brass											
5					.0301	.0172	.0070	.0055	-.0009	-.0022	.0016
6					.0242	.0105	-.0049	-.0112	-.0208	-.0237	-.0258
7					.0069	-.0091	-.0237	-.0525	-.0574	-.0465	-.0665
8					.0259	.0111	.0008	-.0032	-.0140	-.0139	-.0221
Zinc											
9					.0775	.0300	.2027	.2934	.4374	.5605	.6955
10					.0455	.1155	.2137	.2499	.4742	.6705	.5529
11					.0302	.1160	.2559	.3735	.5110	.7859	.5569
12					.0588	.1029	.2061	.2990	.4026	.5491	.6699
Cadmium											
13					-.0059	.0205	.0671	.0591	.0735	.1730	.2569
14					.0259	.0448	.0606	.0913	.1149	.2211	.2955
15					.0030	.0357	.0605	.1005	.1012	.2042	.2615
16					.0235	.0350	.0596	.0923	.0915	.1437	.2576
Pentrated Steel											
17	Failed										
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					Failed						
22					10/10	10/10	10/10	10/10	10/10	10/10	4.5/d/9
23					Failed						
24					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)											
25					10/10	10/10	Failed				
26					9/A/9.5	9/A/9.5	6.5/dA/9	6.5/dA/9	Failed		
27					10/10	10/10	10/10	6/d/9	Failed		
28					10/10	10/10	4.5/d/9	4.5/d/9	Failed		
Nickel-plated Steel											
29	10/10	10/10	10/10	Failed							
30	10/10	10/10	10/10	Failed							
31	10/10	10/10	Failed								
32	10/10	10/10	Failed								
Phosphated Steel											
33	10/10	Failed									
34	10/10	10/10	10/10	Failed							
35	10/10	Failed									
36	10/10	10/10	Failed								

APPENDIX B

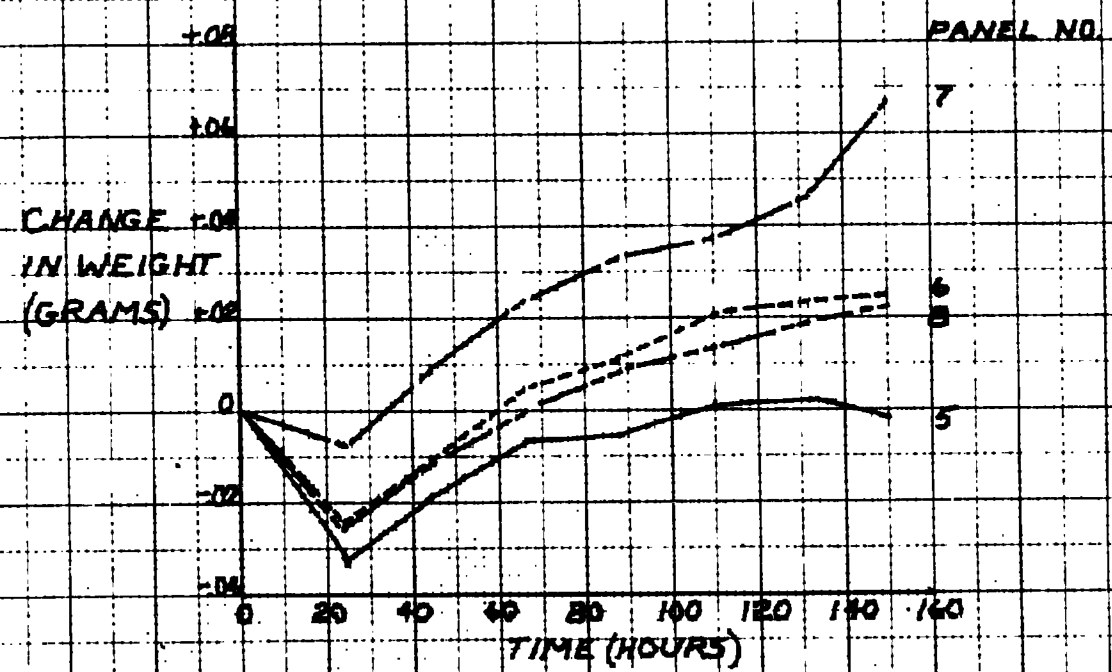
TEST 14

WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 8.0

STEEL

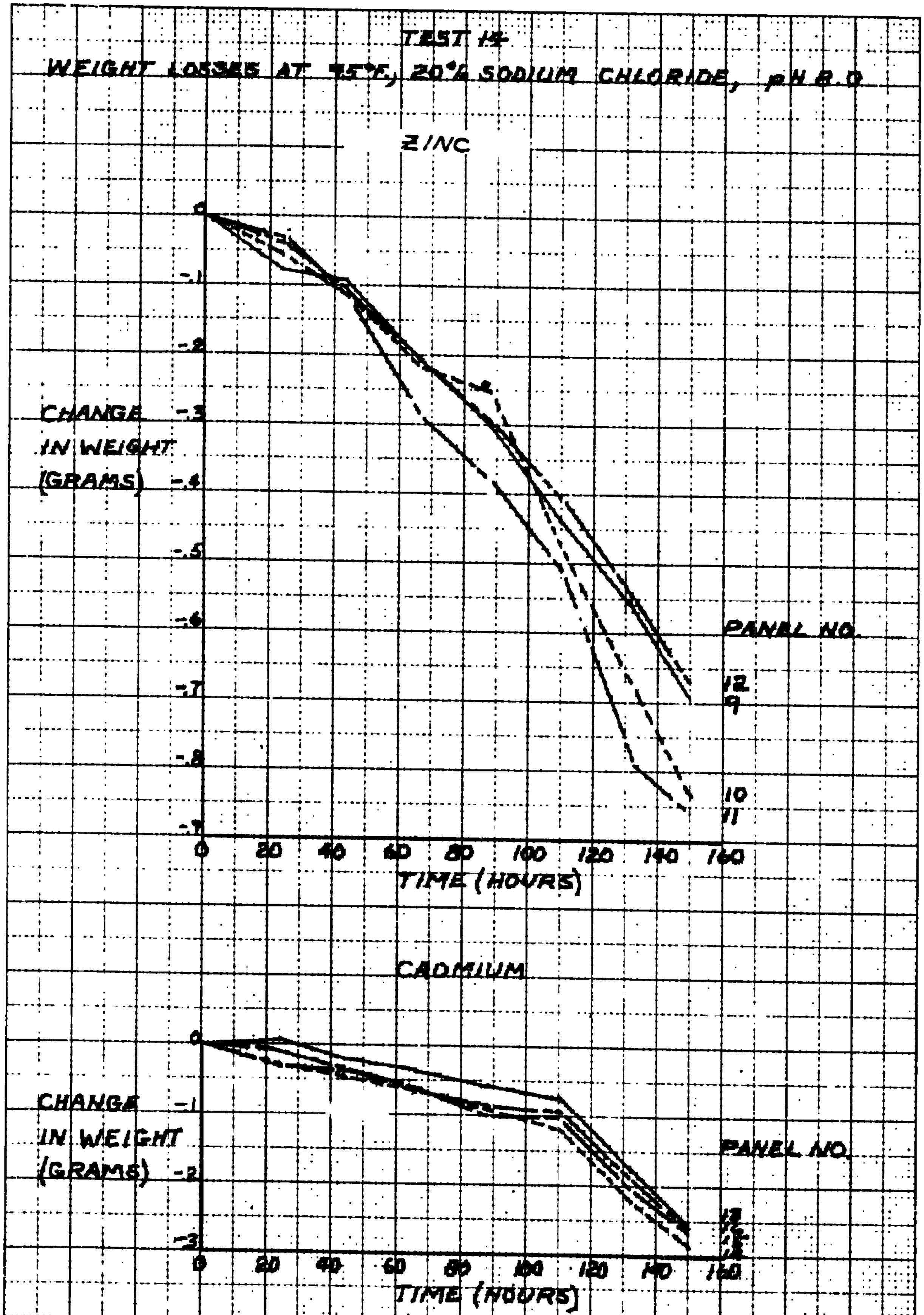


BRASS



THE HENRY SOUTHER ENG. CO.

W.S.J.


TEST 14
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 8.0
ZINC
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
PANEL NO.
12
9
10
11
0 20 40 60 80 100 120 140 160
TIME (HOURS)
CADMIUM
CHANGE IN WEIGHT (GRAMS)
0
-.1
-.2
-.3
PANEL NO.
0 20 40 60 80 100 120 140 160
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.

TEST NO. 15

Object

The object of this test is to determine the corrosive effects of a spray of substitute ocean water at 95°F on the various types of panels used in this series of tests.

Summary

A test has been conducted in the salt spray cabinet at 95°F, using substitute ocean water at pH 8.2.

Introduction

One of the purposes of the salt spray test is to simulate, under accelerated conditions, the effects of natural outdoor corrosion and, more particularly, the corrosive effects of a marine atmosphere. There have been questions raised as to whether the salt spray test measures the resistance to marine atmospheric corrosion. A spray of substitute ocean water has been suggested as a better simulation of the actual conditions of exposure. The results of this test and of Test No. 7 will be compared and these in turn compared to results obtained from actual exposure tests made in a marine atmosphere.

Procedure

A procedure similar to that outlined in Test No. 7 was followed. The substitute ocean water was prepared in accordance with directions included in our first report. The heavy metals mentioned were added. The test was run for 150 hours at 95°F. The cumulative weight losses, panel ratings and a summary of the operating conditions appear in Appendix A. A plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a fairly consistent rate while the brass panels showed no initial loss, but gained weight steadily.

The zinc panels showed a very slight increase in weight as compared with the usual losses in weight.

The cadmium panels lost weight steadily, but the losses were not as great as usual.

The pentrated panels all failed before 1 hour's exposure. Neither the chromic acid nor the sulfuric acid anodized aluminum panels showed any signs of failure at the end of the test period of 150 hours.

The nickel plated steel panels all failed before 2 hour's exposure, and the phosphated steel panels all failed before 1 hour's exposure.

Conclusions

The information obtained from this test will be used as a measure of the corrosive effects of a spray of substitute ocean water. These results will be compared with salt spray and marine atmosphere corrosion rates.

APPENDIX A

TEST NUMBER 15

CORROSION RATES AT 95° F., SUBSTITUTE OCEAN WATER, pH 8.2

LENGTH OF TEST - 150 hours

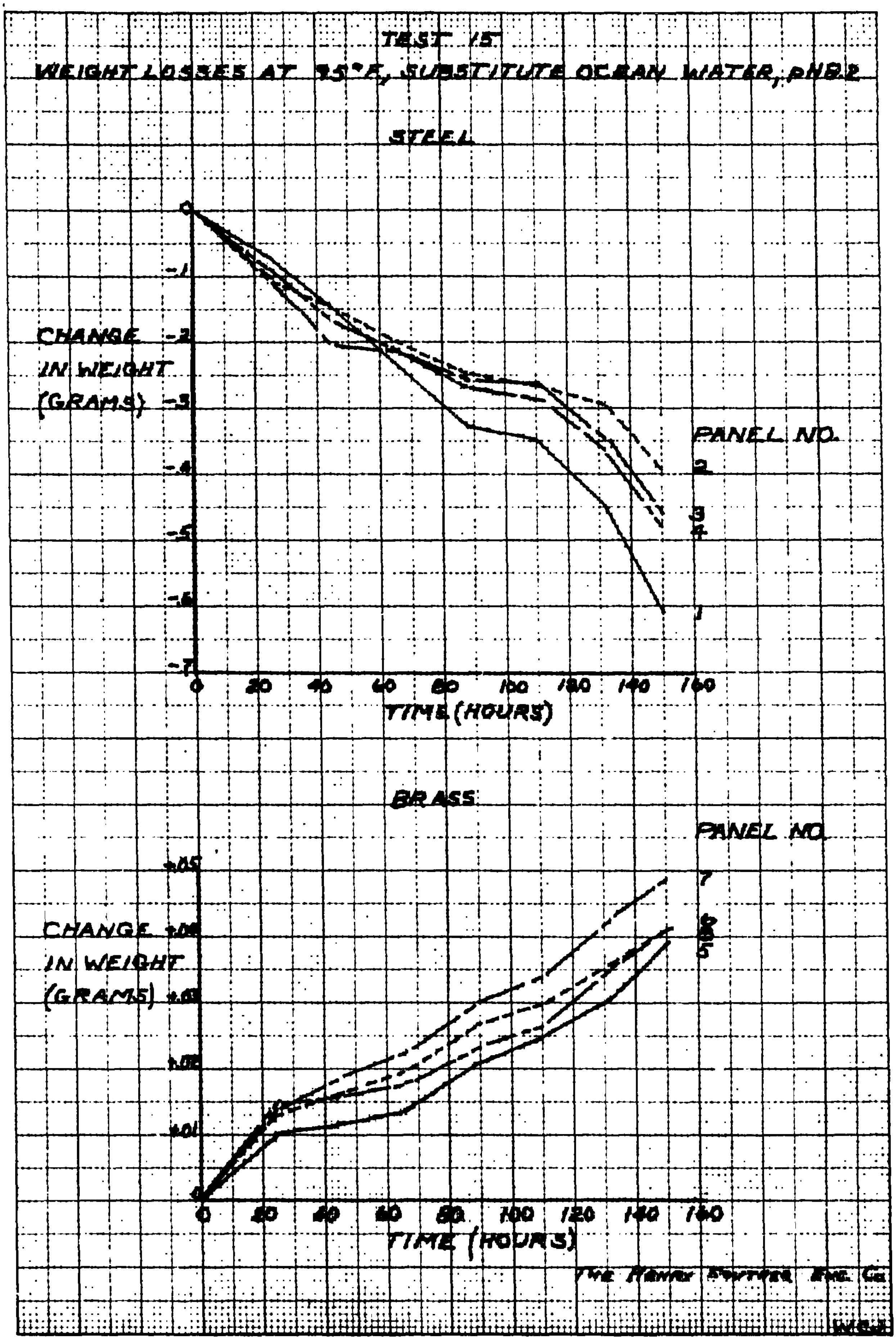
VARIABLE - Composition - substitute ocean water

DATES	3/13/52	3/14/52	3/17/52	[illegible]	3/19/52	3/20/52	3/21/52
Solution Composition	Ocean Water	Ocean Water	Ocean Water	Ocean Water	Ocean Water	Ocean Water	Ocean Water
Dry Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp. (° F.)	95°	95	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (cm./sec.)	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}	5×10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	93°	93°	93°	93°	93°	93°	93°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.48	.46
pH of Solution	8.2	8.2	8.2	8.2	8.2	8.2	8.2
pH of Fog	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Rate of Fog Collection (mls./hr.)	1.2	.7	.7	.9	.7	1.2	1.0
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	—	—	—	—	—	—	—
3. Heavy Metals	—	—	—	—	—	—	—
Specific Gravity of Solution	1.025	1.025	1.025	1.026	1.025	1.025	1.025
Volume of Solution in Reservoir	20 l.	25 l.	20 l.	20 l.	15 l.	20 l.	20 l.

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0698	.1463	.2391	.3254	.3448	.4500	.6030
2					.1010	.1429	.1996	.2486	.2612	.2938	.3941
3					.1008	.2053	.2121	.2559	.2715	.3453	.4594
4					.0848	.1665	.2118	.2656	.2562	.3622	.4767
Brass											
5					-.0102	-.0115	-.0131	-.0206	-.0247	-.0310	-.0393
6					-.0122	-.0159	-.0136	-.0262	-.0295	-.0364	-.0413
7					-.0139	-.0152	-.0223	-.0295	-.033[illegible]	-.0423	-.0467
8					-.0144	-.0158	-.0177	-.0230	-.0266	-.0353	-.0412
Zinc											
9					-.0546	-.0593	-.0774	-.0900	-.1016	-.0992	-.1037
10					-.0064	-.0112	-.0097	-.0205	-.0312	-.0250	-.0198
11					.0067	-.0070	-.0051	-.0171	-.0268	-.0151	-.0172
12					-.0204	-.0367	-.0526	-.0674	-.07[illegible]	-.0778	-.0371
Cadmium											
13					.0219	.0455	.0533	.0822	.1017	.1156	.1239
14					.0233	.0352	.0340	.0681	.0827	.0937	.1076
15					.0213	.0345	.0574	.0812	.1083	.1403	.1506
16					.0215	.04[illegible]5	.0749	.0974	.12[illegible]6	.1514	.1665
Pentrated Steel											
17		Failed									
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (H_2SO_4)											
21					10/10	10/10	10/10	10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10	10/10	10/10	10/10
23					10/10	10/10	10/10	10/10	10/10	10/10	10/10
24					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	10/10	10/10	10/10
26					10/10	10/10	10/10	10/10	10/10	10/10	10/10
27					10/10	10/10	10/10	10/10	10/10	10/10	10/10
28					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Nickel-plated Steel											
29	10/10	10/10	Failed								
30	10/10	Failed									
31	10/10	10/10	10/10	Failed							
32	10/10	10/10	Failed								
Phosphated Steel											
33	10/10	Failed									
34	10/10	Failed									
35	10/10	Failed									
36	10/10	Failed									

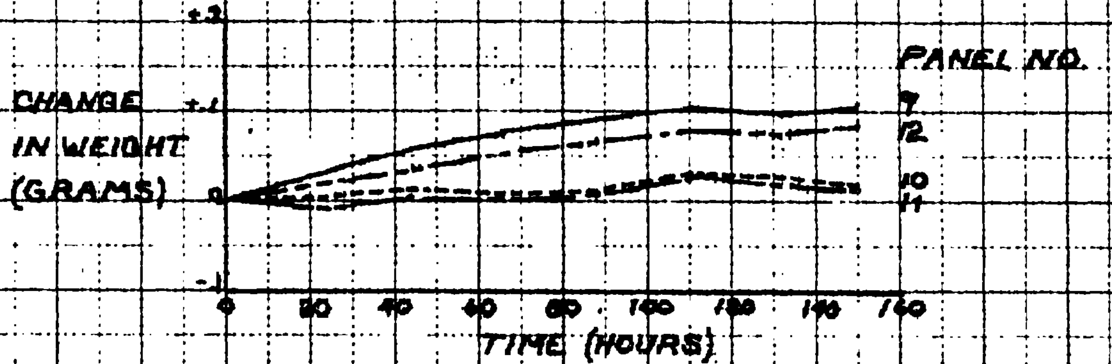
APPENDIX A


TEST 15
WEIGHT LOSSES AT 95°F, SUBSTITUTE OCEAN WATER, pH8.2
STEEL
CHANGE IN WEIGHT (GRAMS)
-1
-2
-3
-4
-5
-6
-7
PANEL NO.
2
3
4
1
0
20
40
60
80
100
120
140
160
TIME (HOURS)
BRASS
PANEL NO.
+.05
+.04
+.03
+.02
+.01
0
7
6
8
5
CHANGE IN WEIGHT (GRAMS)
TIME (HOURS)
The Henry Souther Eng. Co.

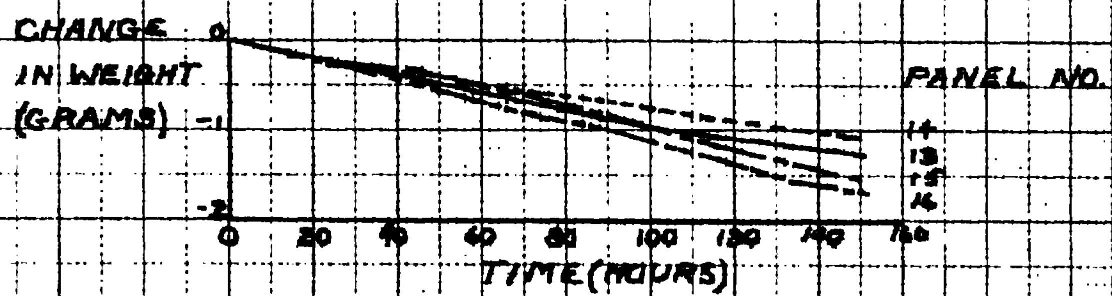
TEST 15

WEIGHT LOSSES AT 95°F, SUBSTITUTE OCEAN WATER, pH 8.2

ZINC



CADMIUM



THE HENRY SOUTHER ENG. CO.

TEST NO. 16

Object

The object of this test is to determine the effect of the presence of iodide ions in appreciable quantity in the salt solution used to generate the fog in salt spray testing.

Summary

A test has been run at 95°F in the salt spray test cabinet using a 20% sodium chloride solution, pH 7.0, with a 0.1% addition of iodide ion in the form of sodium iodide. Conditions of operation and types of panels exposed were the same as previously described, the only difference being the addition of iodide ion.

Introduction

Specifications detailing the procedure for salt spray testing require the use of iodide-free salt. The effect of another halogen ion besides chlorine on the rate of corrosion should therefore be determined from the standpoint of possible substitution of commercial grades of plain or iodized salt. Results of this test will be used in comparison with those under the same operating conditions, using C.P. 20% sodium chloride solution.

Procedure

A procedure similar to that outlined in Test No. 7 was followed. The test was run for a period of 150 hours, using a solution composed of 20% sodium chloride and 0.1% sodium iodide in distilled water, the pH being adjusted to 7.0. A summary of the operating conditions, cumulative weight losses and panel ratings are shown in Appendix A, while a plot of the cumulative weight losses of the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a fairly steady rate and no change was noted in the order of the rate of corrodibility with box position (i.e., 2, 3, 4, 1). The brass panels, after initial losses, gained weight in the manner usually experienced.

The zinc panels and cadmium panels showed steady losses of a magnitude greater than that generally experienced.

The pentrated steel panels all failed before 1/2 hour's exposure, while the aluminum panels, anodized by both the chromic and sulphuric acid processes, showed varied results with little possibility of comparison.

The nickel plated steel all failed in between 1-1/2 and 2 hours exposure.

Three of the phosphated steel panels failed before 1 hour's exposure, while the other failed before 2 hours.

<u>Conclusion</u>

These data constitute a measure of the corrosion rate with a 0.1% addition of sodium iodide, and will be used in comparison with the results from Test No. 7 to determine the effect of iodide ion on the rate of corrosion.

APPENDIX A

TEST NUMBER 10

CORROSION RATES AT 95° F., .1% IODIDE in 20% SODIUM CHLORIDE, pH 7.0

LENGTH OF TEST - 150 hours

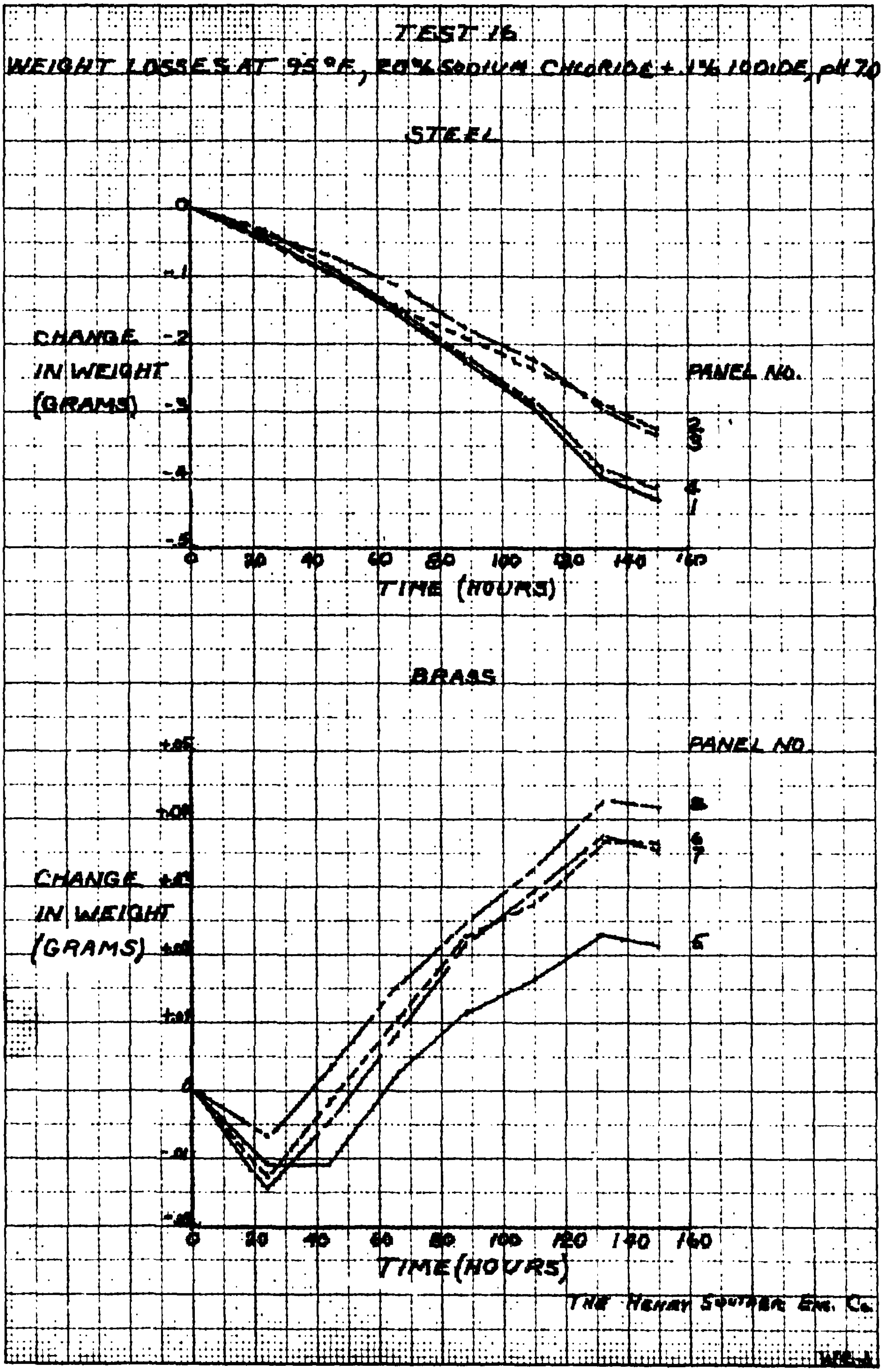
VARIABLE - Iodide concentration - .1%

DATES	3/23/52	3/24/52	3/25/52	3/26/52	3/27/52	3/28/52	3/2[illegible]/52
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (mm./sec.)	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}	4 x 10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.46	.46
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	1.1	1.0	.9	1.1	1.0	1.0	1.0
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.9%	99.8%
2. Br and I	.1% I⁻	.1% I⁻	.1% I⁻	.1% I⁻	.1% I⁻	.1% I⁻	.1% I⁻
3. Heavy Metals	——	——	——	——	——	——	——
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	56 hrs.	8[illegible] hrs.	110 hrs.	132 hrs.	150 hrs.
Steel											
1					.0442	.0919	.1574	.2245	.2950	.3960	.4584
2					.0448	.0933	.1452	.1294	.2464	.2871	.3228
3					.0417	.0658	.1126	.1720	.2208	.2958	.3293
4					.0404	.0562	.1558	.2225	.2584	.3864	.4277
Brass											
5					.0108	.0108	-.0080	-.0119	-.0154	-.0250	-.0214
6					.0184	.0018	-.0107	-.0229	-.0272	-.0367	-.0367
7					.0141	.0043	-.0058	-.0215	-.0293	-.0374	-.0856
8					.0064	-.0054	-.0155	-.0243	-.0324	-.0482	-.0411
Zinc											
9					-.0106	.0744	.1421	.3191	.4155	.5208	.3798
10					.0288	.1089	.2045	.2745	.4198	.6100	.5890
11					.0047	.0795	.1559	.2879	.4045	.6110	.7605
12					-.0318	.0457	.1402	.2337	.3111	.3968	.6210
Cadmium											
13					.0584	.0949	.1832	.1794	.2635	.2295	.3571
14					.0807	.0742	.1703	.1533	.2464	.3153	.4257
15					.0377	.0736	.1835	.2083	.2651	.3122	.4567
16					.0425	.0751	.1404	.1747	.2472	.3097	.3444
Pentrated Steel											
17	Failed										
18	Failed										
19	Failed										
20	Failed										
Anodized Aluminum (HNO_3)											
21					10/10	10/10	10/10	10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10	10/10	10/10	10/10
23					Failed						
24					Failed						
Anodized aluminum											
25					10/10	10/10	10/10	Failed			
26					10/10	10/10	10/10	4.5/4/9	Failed		
27					10/10	10/10	10/10	10/10	4/4/9	Failed	
28					10/10	10/10	10/10	10/10	4/4/9	4/4/9	4/4/9
Nickel-plated Steel											
29	10/10	10/10	10/10	Failed							
30				Failed							
31				Failed							
32				Failed							
Phosphated Steel											
33	10/10	Failed									
34	10/10	Failed									
35	10/10	Failed									
36	10/10	10/10	10/10	Failed							

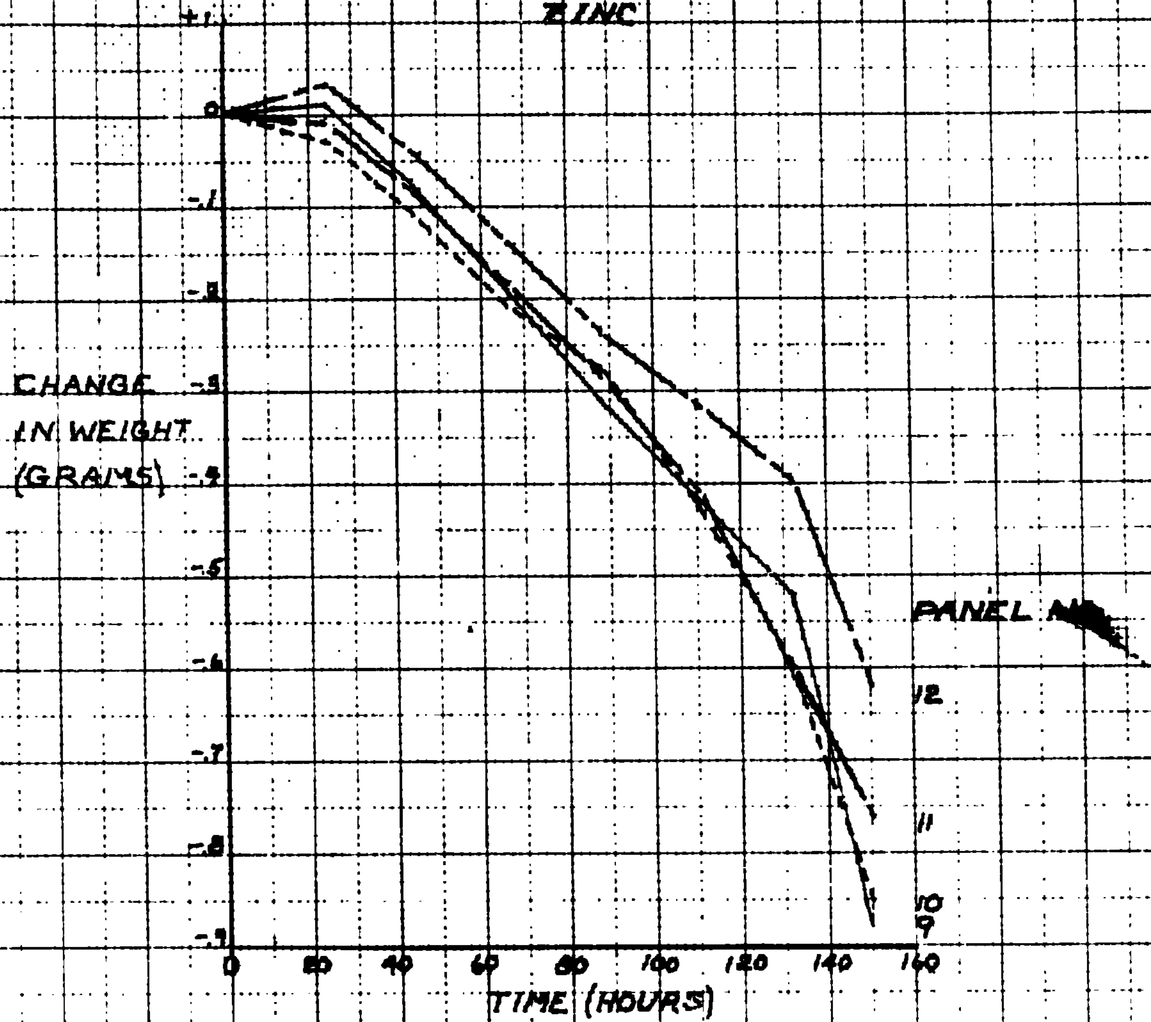
APPENDIX B


TEST 16
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE + 1% IODIDE, pH 7.0
STEEL
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
2
3
4
1
TIME (HOURS)
BRASS
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
8
6
7
5
TIME (HOURS)
THE HENRY SOUTHER ENG. Co.

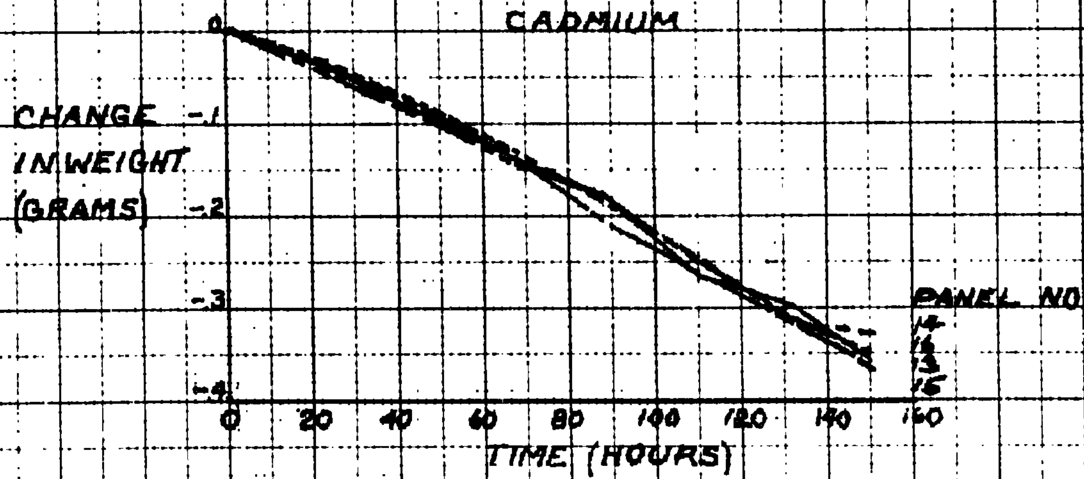
TEST 16

WEIGHT LOSSES AT 75° F, 20% SODIUM CHLORIDE + 1% IODIDE, pH 7.0

ZINC



CADMIUM



The Henry Souther Eng. Co.

TEST NO. 17

Object

The object of this test is to determine the effect of reducing the size of the salt spray fog particles on the rate of corrosion in the salt spray test cabinet.

Summary

A test has been conducted at 95°F using a 20% salt solution, pH 7.0, and a modified atomizing nozzle so as to produce a fog of substantially reduced particle size. The same operating conditions and types of panels were used as have been employed in the previous tests, the only variable from standard conditions being the particle size.

Introduction

The particle size, although not directly specified in the description of standard salt spray test requirements, directly affects the wetness and density of the fog produced and, therefore, should have some bearing on the rate of corrosion. This test, made with a fog of reduced particle size, will be used in comparison with Test No. 7 which represents the same conditions with the exception of a larger particle size.

Procedure

A procedure similar to that outlined in Test No. 7 was followed. The change in particle size was brought about by a slight increase in diameter of the hole feeding the salt solution into the air jets. The test was conducted for a period of 150 hours at 95°F, using a 20% sodium chloride solution, pH 7.0. A summary of the operating conditions, cumulative weight losses and panel ratings comprises Appendix A while a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels is found in Appendix B.

Discussion

The steel panels lost weight in accordance with their usual pattern. The brass panels, after initial losses, gained weight steadily and in every case exceeded their original weight before the end of the test.

The zinc panels lost weight from the beginning of the test, and the cadmium panels showed very steady and closely grouped weight losses.

Three of the pentrated steel panels failed before 1/2 hour, while the fourth failed before 1-1/2 hours.

Anodized aluminum panels prepared by the chromic acid process showed superiority over those prepared by the sulphuric acid process, three of these failing before 24 hours exposure.

The nickel plated steel panels all failed before 24 hours exposure, and the phosphated steel panels all failed before 1-1/2 hours exposure.

Conclusions

These data constitute a measure of the corrosion rate at standard conditions with a reduced particle size, and will be used in comparison with Test No. 7 to determine the effect of particle size on the rate of corrosion.

APPENDIX A

TEST NUMBER 17

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

LENGTH OF TEST – 150 hours

DATES	3/21/52	3/29/52	3/30/52	3/31/52	4/1/52	4/2/52	4/3/52
	VA TABLE – Particle size						
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.1	.1	.1	.1	.1	.1	.1
Rate of Settling (cm./sec.)	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}
Air Pressure (lbs./in.^{2})	11.5	11.5	11.5	11.5	11.5	11.5	11.5
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.48	.48	.48	.48	.48	.48	.48
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (ml./hr.)	9	.8	1.0	.9	.9	1.0	.9
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.5%	99.3%	99.5%	99.8%	99.8%
2. Br and I	——	——	——	——	——	——	——
3. Heavy Metals	——	——	——	——	——	——	——
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

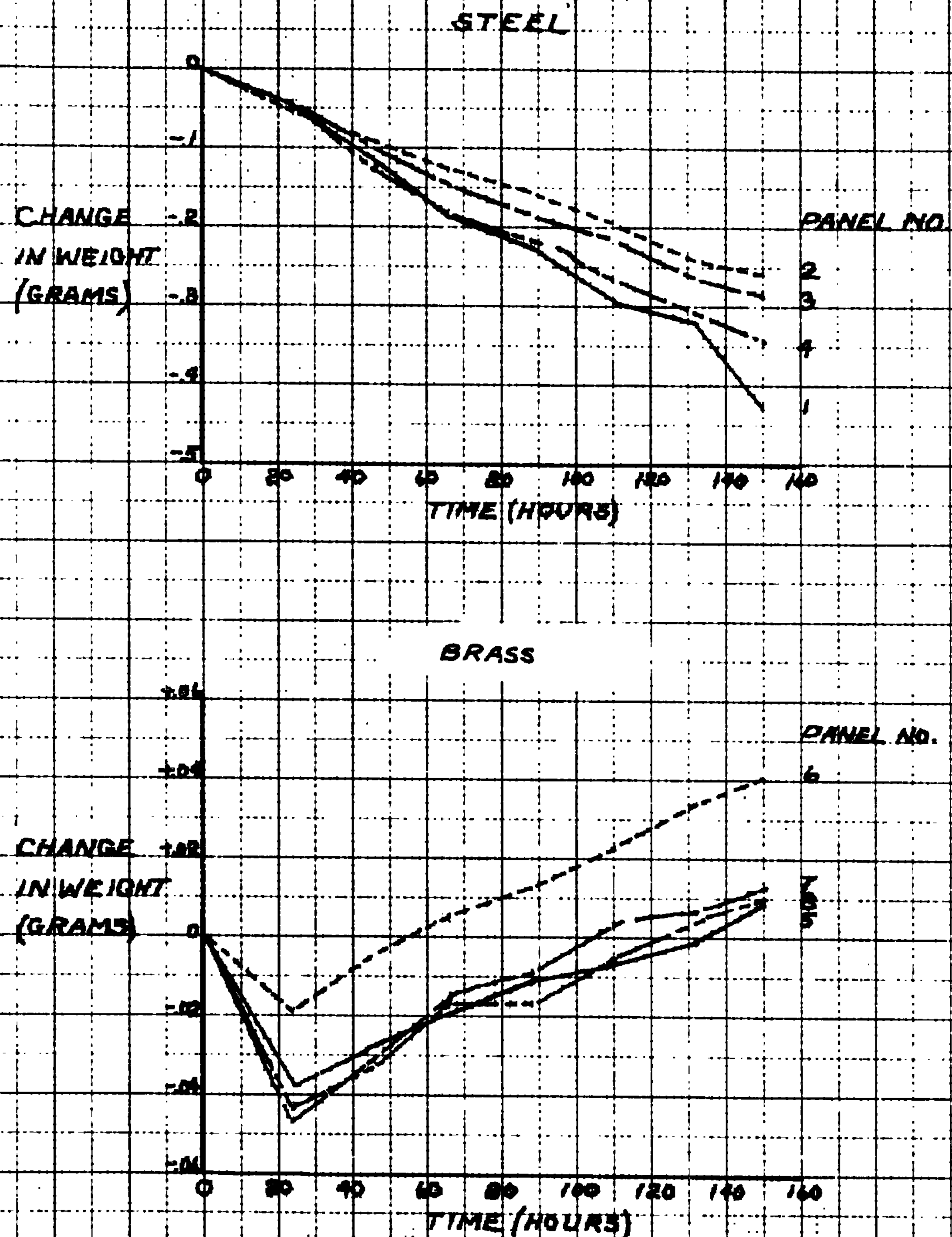
PANEL NUMBER	1/2 hrs.	1 hr.	1.5 hrs.	2 hrs.	5 hrs.	24 hrs.	44 hrs.	66 hrs.	88 hrs.	110 hrs.	132 hrs.	150 hrs.
Steel												
1						.0298	.1023	.1370	.2233	.2716	.3176	.4295
2						.0508	.0393	.1274	.1557	.1943	.2404	.2660
3						.0442	.0960	.1497	.1822	.2121	.2525	.2808
4						.0481	.1156	.1457	.2183	.2678	.3027	.3416
Brass												
5						.0379	.0256	.0134	.0111	.0065	.0004	–.0055
6						.0188	.0058	–.0054	–.0125	–.0220	–.0659	–.0404
7						.0467	.0318	.0151	.0056	–.0052	–.0069	–.0128
8						.0425	.0327	.0163	.0165	.0055	–.0048	–.0098
Zinc												
9						.0594	.1504	.2564	.2663	.3475	.4754	.6520
10						.1004	.2060	.2794	.3091	.4234	.5613	.5964
11						.1307	.3184	.3751	.4286	.5269	.5901	.7450
12						.1407	.2701	.3194	.3640	.4820	.6320	.5132
Cadmium												
13						.0514	.0983	.1314	.1532	.2085	.2412	.2338
14						.0468	.0707	.1271	.1576	.2006	.2330	.2759
15						.0404	.0754	.1132	.1307	.2081	.2379	.2727
16						.0481	.0705	.1247	.1304	.2150	.2474	.2954
Pentrated Steel												
17	Failed											
18	Failed											
19	10/10	10/10	Failed									
20	Failed											
Anodized Aluminum (H_2SO_4)												
21						Failed						
22						Failed						
23						Failed						
24						10/10	10/10	10/10	9/d/9	9/d/9	8/d/9	Failed
Anodized Aluminum (CrO_3)												
25						10/10	2.5/d/9	Failed				
26						10/10	10/10	9/d/9	6/d/9	6/d/9	Failed	
27						10/10	4/d/9	Failed				
28						10/10	10/10	3.5/d/9	4.5/d/9	4.5/d/9	Failed	
Nickel-plated Steel												
29	10/10	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed							
31	10/10	10/10	10/10	10/10	Failed							
32	10/10	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel												
33	10/10	10/10	Failed									
34	10/10	10/10	Failed									
35	10/10	10/10	Failed									
36	10/10	10/10	Failed									

APPENDIX B

TEST 17

WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0

PARTICLE SIZE VARIATION

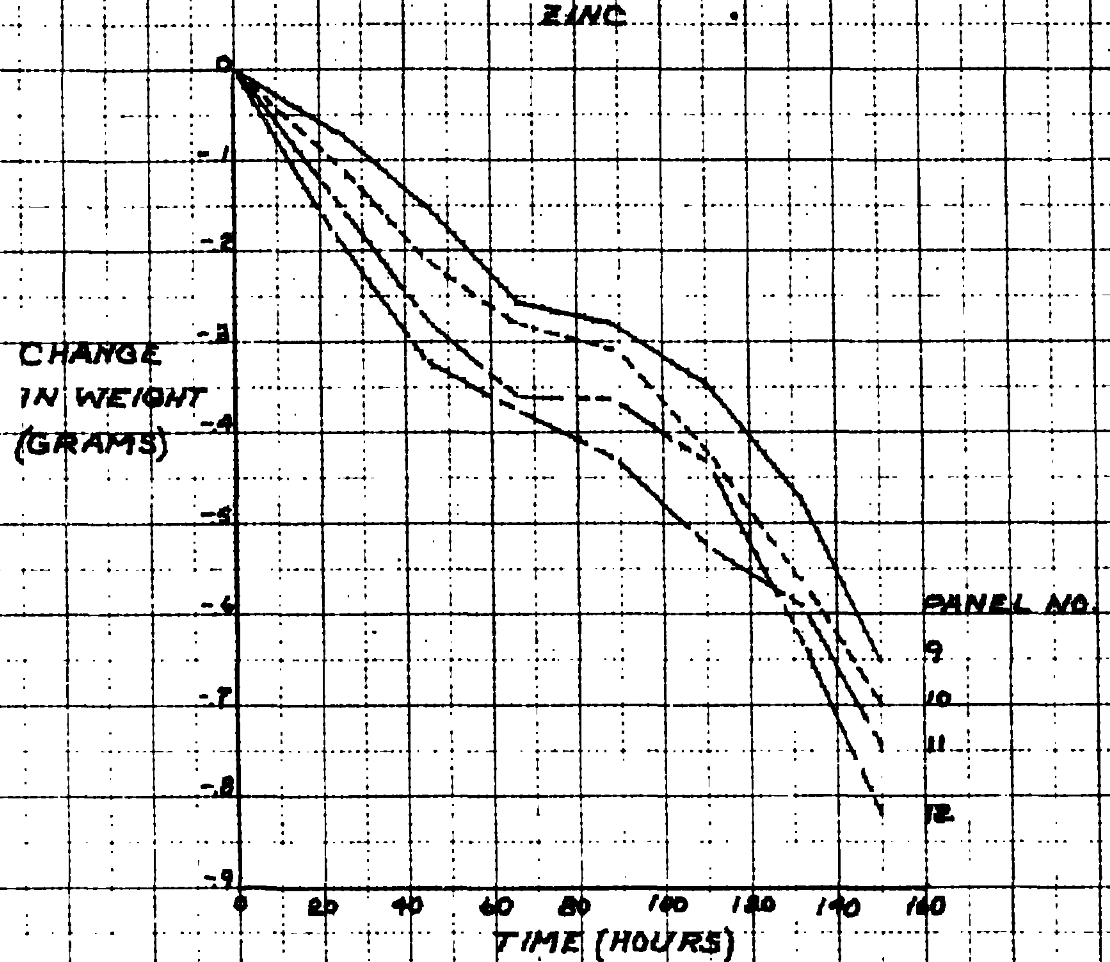


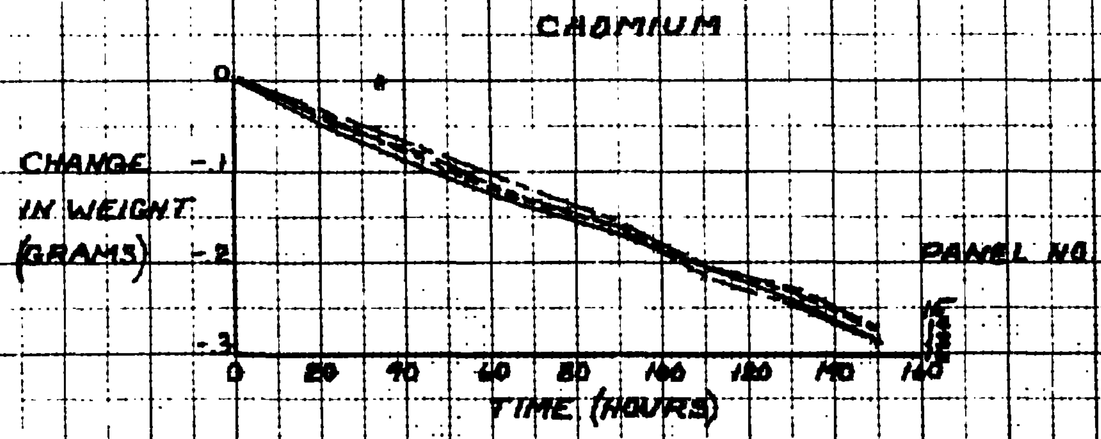
THE HENRY SOUTHER ENG. CO.

TEST 17

WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0

PARTICLE SIZE VARIATION





The Henry Souther Eng. Co.

TEST NO. 18

Object

The object of this test is to determine the effect of a fog formed by spraying distilled water on the nine types of material previously used in the foregoing series of salt spray tests.

Summary

A test has been conducted at 95°F in the salt spray test cabinet for a period of 150 hours using, as the test solution, distilled water adjusted to pH 7.0.

Introduction

A spray of distilled water has been suggested as a possible substitute for salt spray in accelerated corrosion testing. This test, using distilled water, will be used as a measure of the effectiveness of this method and will also be used in comparison with the results obtained from salt spray, humidity, and outdoor exposure tests.

Procedure

The salt spray test cabinet was thoroughly cleaned with water to remove the salt adhering to the box, and was repeatedly rinsed with city water until rinsings showed only a very slight haze when tested with 0.14 N silver nitrate solution. The box was then operated with a distilled water spray for 24 hours and drained before the test panels were put in. The test panels were prepared and evaluated in the manner described in Test No. 7. The test was run for a period of 150 hours, using distilled water with the pH adjusted to 7.0. A summary of the operating conditions, cumulative weight losses and panel ratings is shown in Appendix A while a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at every inspection, but the rate of loss was not as steady as has been experienced with salt solution.

The brass panels showed little or no initial loss, and their weight gains were extremely low and erratic.

The zinc panels lost weight after 24 hours exposure, and the cadmium panels lost weight at a steady rate and in a closely grouped pattern.

The pentrated steel panels all failed before 2 hours exposure, while neither the sulphuric nor the chromic acid anodized aluminum panels showed any evidence of attack after the 150-hour test period.

The nickel plated steel panels all failed before 24 hours exposure and the phosphated steel panels all failed before 2 hours exposure.

Conclusion

These data constitute a measure of the corrosive effects of a spray of distilled water and will be evaluated by comparison with results obtained from salt spray, humidity and outdoor city and marine exposure tests.

APPENDIX A

TEST NUMBER 18

CORROSION RATES AT 95°, DISTILLED WATER, pH 7.0

VARIABLE - Composition - Distilled Water

DATES	4/8/52	4/9/52	4/10/52	4/11/52	4/12/52	4/13/52	4/14/52
Solution Composition	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O	Dist. H_2O
Dry Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (cm./sec.)	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}	2×10^{-4}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.44	.44	.44	.44	.44	.44	.44
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	.9	.9	.9	1.1	1.0	1.0	1.0
Impurities in Solution	—	—	—	—	—	—	—
Specific Gravity of Solution	1.001	1.001	1.001	1.001	1.001	1.001	1.001
Volume of Solution in Reservoir	4 gals.	4 gals.	4 gals.	4 gals.	4 gals.	4 gals.	4 gals.

LENGTH OF TEST - 150 hours

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

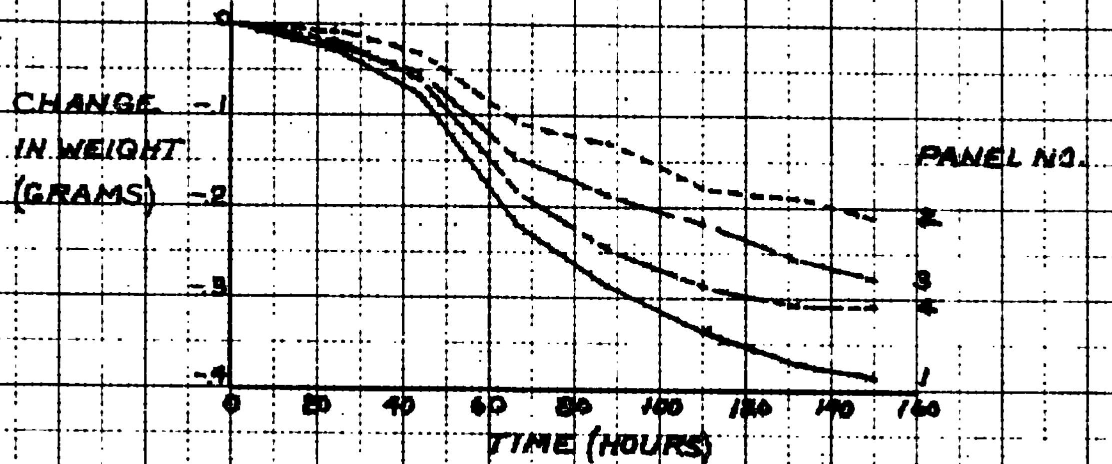
PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	24 hrs.	44 hrs.	68 hrs.	92 hrs.	116 hrs.	132 hrs.	150 hrs.
Steel											
1					.0235	.0735	.2152	.2422	.3579	.3731	.4738
2					.0049	.0810	.1063	.1250	.1796	.1575	.2097
3					.0215	.0501	.1441	.1502	.2171	.2533	.3747
4					.0177	.0992	.1914	.2422	.2914	.3048	.4077
Brass											
5					.0022	.0010	-.0006	-.0086	-.0047	-.0045	-.0084
6					-.0022	-.0049	-.0046	-.0072	-.0099	-.0105	-.0059
7					-.0082	-.0045	-.0025	-.0046	-.0058	-.0021	-.0038
8					.0004	-.0017	-.0044	-.0050	-.0031	-.0088	-.0016
Zinc											
9					.0080	.0255	.0867	.0895	.0990	.1497	.1938
10					-.0009	.0458	.1152	.2124	.2569	.3112	.3906
11					-.0052	.0340	.0579	.1458	.1345	.2833	.3208
12					-.0024	.0469	.0727	.1172	.1297	.1642	.2157
Cadmium											
13					.0056	.0501	.0425	.0701	.1005	.1502	.1657
14					.0091	.0314	.0693	.0554	.1131	.1595	.1656
15					.0031	.0233	.0673	.0723	.0957	.1229	.1455
16					.0115	.0249	.0593	.0771	.0957	.1225	.1371
Bonderized Steel											
17	10/10	Failed									
18	10/10	10/10	Failed								
19	10/10	10/10	10/10	Failed							
20	10/10	Failed									
Anodized Aluminum (H_2SO_4)											
21					10/10	10/10	10/10	10/10	10/10	10/10	10/10
22					10/10	10/10	10/10	10/10	10/10	10/10	10/10
23					10/10	10/10	10/10	10/10	10/10	10/10	10/10
24					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)											
25					10/10	10/10	10/10	10/10	10/10	10/10	10/10
26					10/10	10/10	10/10	10/10	10/10	10/10	10/10
27					10/10	10/10	10/10	10/10	10/10	10/10	10/10
28					10/10	10/10	10/10	10/10	10/10	10/10	10/10
Nickel-plated Steel											
29	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed						
31	10/10	10/10	10/10	Failed							
32	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel											
33	10/10	10/10	10/10	Failed							
34	10/10	10/10	10/10	Failed							
35	10/14	10/10	10/10	Failed							

APPENDIX B

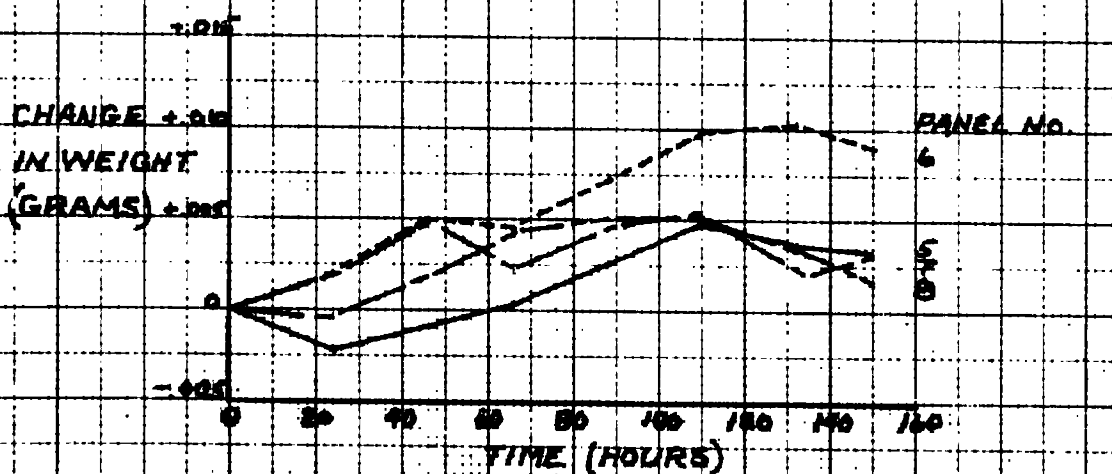
TEST 18

WEIGHT LOSSES AT 95°F, DISTILLED WATER, pH 7.0

STEEL



BRASS



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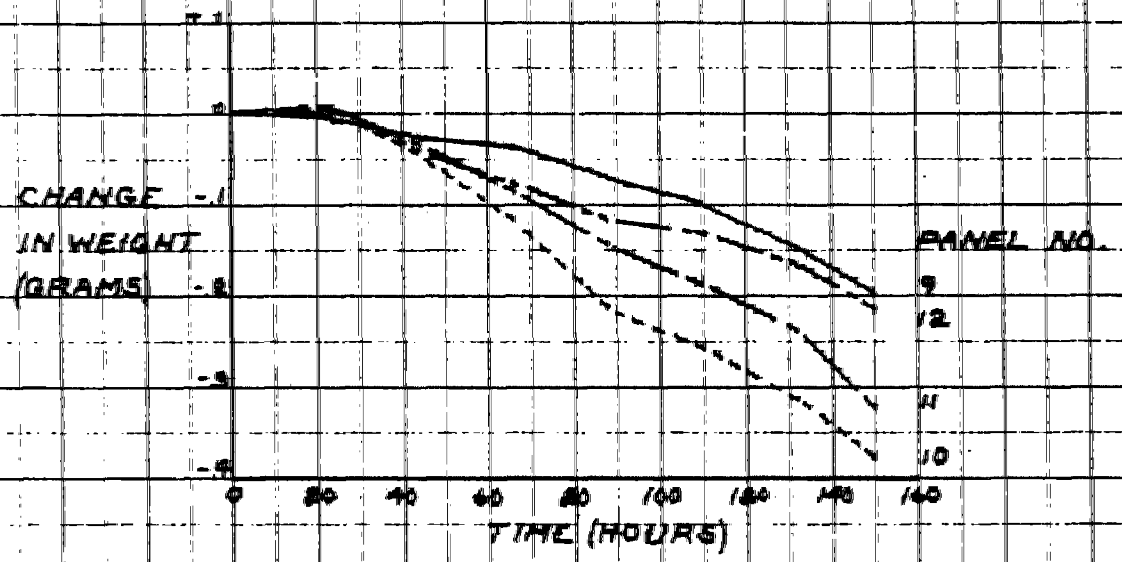
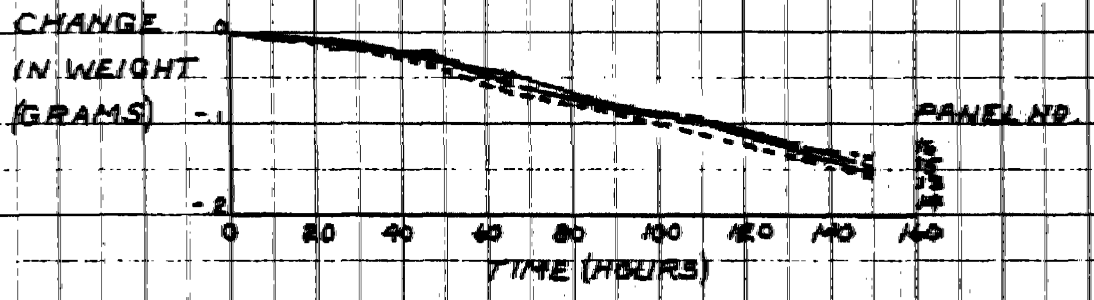
TEST 18

WEIGHT LOSSES AT 95°F, DISTILLED WATER, pH 7.0

ZINC



CADMIUM



THE HENRY SOUTHER ENG. CO.

The cadmium panels lost weight steadily.

The pentrated steel panels all failed before 1 hour's exposure.

The chromic acid anodized aluminum panels proved superior to those prepared by the sulphuric acid process.

The nickel plated steel panels all failed before 24 hours exposure and phosphated steel panels before 2 hours.

Conclusions

These data constitute a measure of the corrosion rate at 95°F, using a 20% sodium chloride solution, pH 7.0, and will be used in comparison with Test No. 7 to determine the reproducibility of one particular salt spray test.

APPENDIX A

TEST NUMBER 12

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

DATES	4/16/52	4/17/52	4/18/52	4/19/52	4/20/52	4/21/52	4/22/52
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp. (° F.)	95°	95°	95°	95°	95	95	95°
Wet Bulb Temp. (° F.)	95°	95	95	95	95	95°	95
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (cm./sec.)	3×10^{-5}	3×10^{-5}	3×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-6}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12
Air Temp. (° F.)	95°	95°	95°	95°	95°	95	95°
Rate of Flow (ft.^{3}/min.)	.44	.44	.44	.44	.44	.44	.44
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	1.2	1.2	1.2	1.2	1.1	1.2	1.4
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	—	—	—	—	—	—	—
3. Heavy Metals	—	—	—	—	—	—	—
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

LENGTH OF TEST - 156 hours

CUMULATIVE WEIGHT LOSSES (grams) and RATINGS

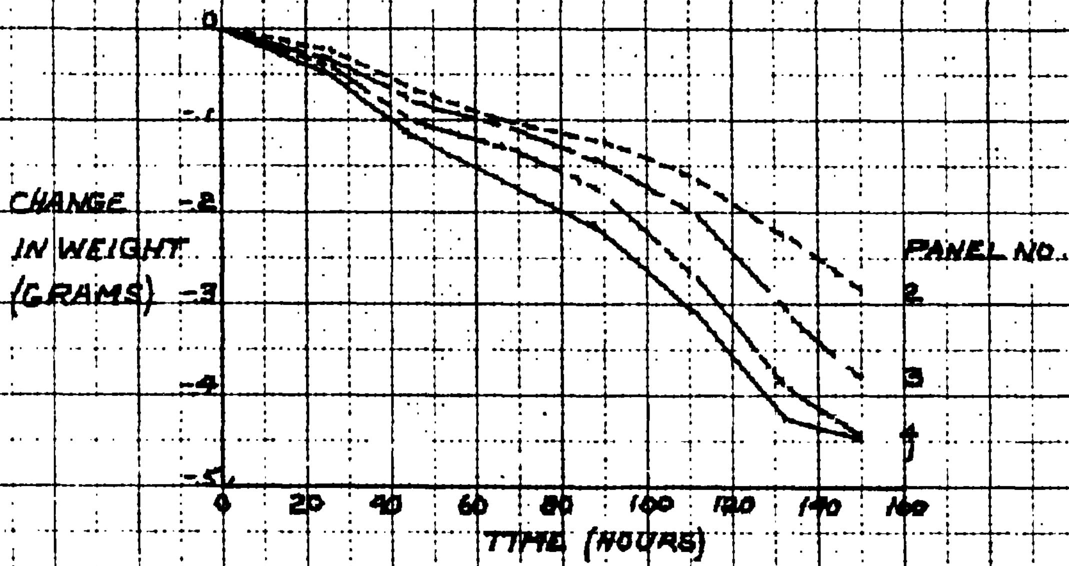
PANEL NUMBER	1/2 hr.	1 hr.	1 1/2 hrs.	2 hrs.	4 hrs.	24 hrs.	44 hrs.	86 hrs.	98 hrs.	128 hrs.	134 hrs.	156 hrs.
Steel												
1						.0417	.1154	.1609	.2142	.3076	.4261	.4454
2						.0195	.0627	.0936	.1290	.1611	.2248	.2930
3						.0246	.0754	.1051	.1414	.1934	.3052	.3735
4						.0281	.0944	.1282	.1757	.2567	.3332	.4424
Brass												
5						.0361	.0240	.0146	.0066	.0074	.0389	.3067
6						.0296	.0177	.0057	-.0065	-.0149	-.0129	-.0284
7						.0342	.0214	.0046	-.0020	-.0602	-.0182	-.0254
8						.0560	.0163	.0039	-.0019	-.0068	-.0082	-.0129
Zinc												
9						.0629	.0977	.1499	.2770	.2902	.5759	.7734
10						.0539	.1190	.1610	.2296	.4684	.7112	.9953
11						.0529	.1572	.2266	.3247	.4340	.6876	.9398
12						.0376	.1548	.1909	.2555	.4111	.5527	.7797
Cadmium												
13						.0129	.0691	.1023	.1601	.1759	.1545	.2985
14						.0451	.0951	.1255	.1769	.2181	.2781	.3791
15						.0150	.0567	.0953	.1320	.1575	.1714	.2954
16						.0432	.0555	.1153	.1555	.1900	.2400	.3283
Penetrated Steel												
17	10/10	Failed										
18	10/10	Failed										
19	10/10	Failed										
20	10/10	Failed										
Anodized Aluminum (H_2SO_4)												
21						10/10	10/10	8/d/9	8/d/9	8/d/9	Failed	
22						4.2/dS/9	Failed					
23						3/dS/9	3/dS/9	Failed				
24						5.8/dS/9	4.2/dS/9	4/dS/9	Failed			
Anodized Aluminum (CrO_3)												
25						10/10	10/10	10/10	10/10	10/10	2.5/d/9	2.5/d/9
26						10/10	8/d/9	5.5/d/9	6.8/d/9	6.5/d/9	4.5/d/9	Failed
27						10/10	10/10	10/10	10/10	10/10	10/10	10/10
28						10/10	10/10	10/10	10/10	10/10	10/10	10/10
Nickel-plated Steel												
29	10/10	10/10	10/10	10/10	10/10	Failed						
30	10/10	10/10	10/10	10/10	Failed							
31	10/10	10/10	10/10	10/10	Failed							
32	10/10	10/10	10/10	10/10	10/10	Failed						
Phosphated Steel												
33	10/10	10/10	10/10	Failed								
34	10/10	10/10	Failed									
35	10/10	10/10	Failed									
36	10/10	10/10	Failed									

APPENDIX B

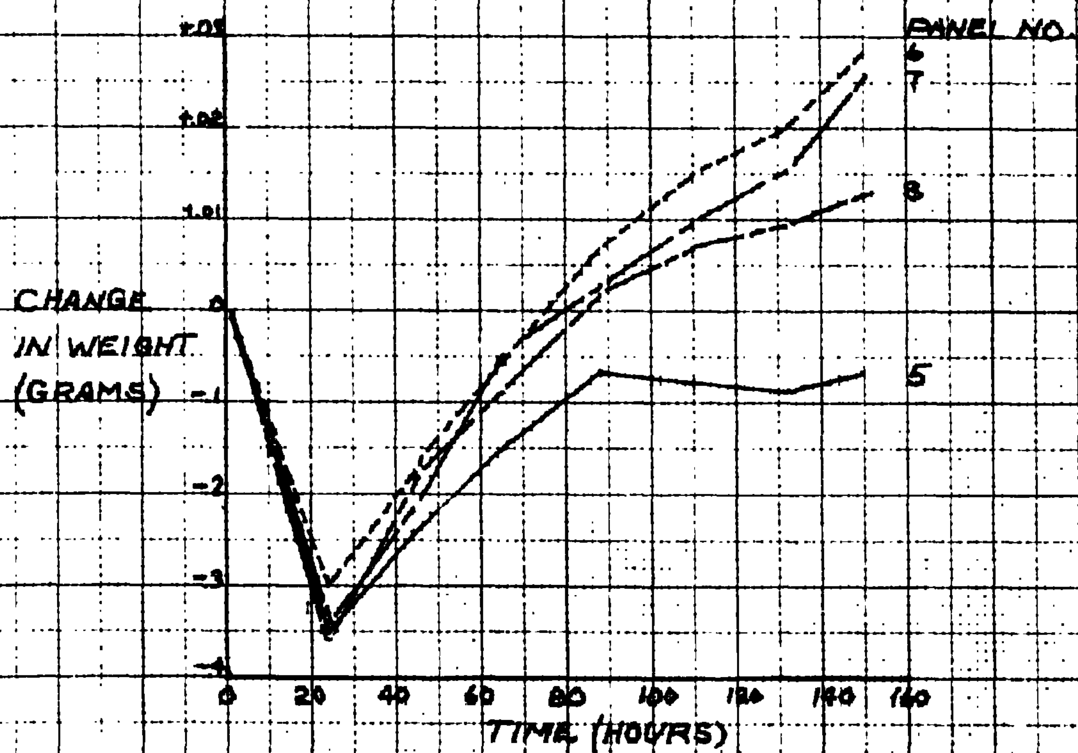
TEST 19

WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0

STEEL



BRASS



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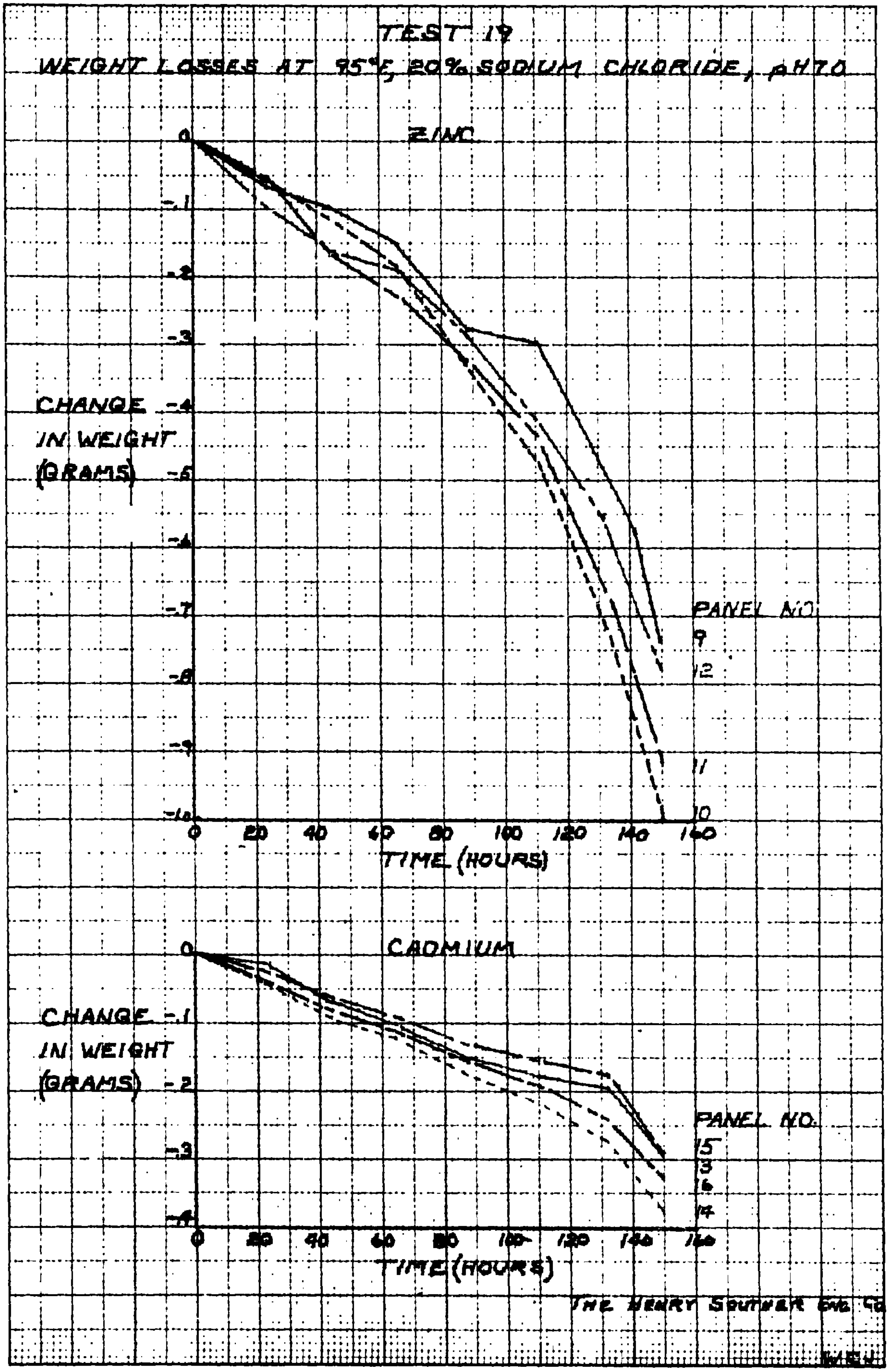

TEST 19
WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0
ZINC
CHANGE IN WEIGHT (GRAMS)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
PANEL NO.
9
12
11
10
0
20
40
60
80
100
120
140
160
TIME (HOURS)
CADMIUM
CHANGE IN WEIGHT (GRAMS)
0
-1
-2
-3
-4
PANEL NO.
15
3
16
14
0
20
40
60
80
100
120
140
160
TIME (HOURS)
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TEST NO. 20

Object

The object of this test is to determine the effect of the angle of exposure in a salt spray test on the rate of corrosion.

Summary

A test has been run at 95°F with 20% sodium chloride solution, pH 7.0, and steel panels. The panels were held at every 10 degrees of rotation through a full circle, only one side being exposed to the salt spray. In addition, panels were exposed at 15° from the vertical.

Introduction

What constitutes a significant surface in salt spray testing has been variously described and, in some cases, reference is made to a certain angle of exposure (e.g. 15° from vertical for phosphate finishes and 6° for anodized aluminum). This test, then, is an attempt to measure the dependency of the rate of corrosion on the angle of exposure and also the effect of the direction of the flow of fog on the rate of corrosion.

Procedure

Forty 2" x 3" low carbon steel panels were abraded with a 240 grit Aloxite cloth, and one side of each panel covered with Scotch brand No. 33 electrical tape to protect from corrosion. The panels were then cleaned in A-1 cleaner solution, water rinsed, dried and weighed to the nearest tenth of a milligram. Twenty polystyrene holders were made, each with two milled slots at the desired angle of exposure. Two panels were placed back to back with the unprotected sides out in each rack. A photograph of the assembled holders with and without the panels is shown in Appendix C.

Panels were held in such a manner as to expose one panel at every 10° of rotation through a full circle. Additional holders were used to expose panels at 15° from the vertical. Panels were so placed that the axis around which the panels were rotated was at right angles to the direction of the principal flow of fog in the box. The panels were placed in the box so that no one holder shielded another and each was exposed directly to the fog. A summary of the operating conditions appears in Appendix A.

The test was run for a period of 24 hours, after which the panels were removed from the box, scrubbed with a nylon bristle brush under running water, dried and reweighed to the nearest tenth of a milligram.

Weight losses were then computed and are shown in Appendix A. A plot of these weight losses versus the angle of exposure comprises Appendix B.

Discussion

Results show a clear dependency of rate of corrosion on the angle of exposure and on the position of the panels with respect to the principal direction of flow of fog. The angle of exposure is more critical and has a pronounced effect on the rate of corrosion. Corrosion on the underside was of a different character than that on the upper side of the panel. Corrosion on the underside was characterized by a dark, finer-grained, adherent cover of rust that is not readily removed by scrubbing. Weight gains rather than losses were, therefore, experienced. Corrosion products on the upper surfaces were of a "coarser" nature and lighter in color. They were easily removed by scrubbing, resulting in weight losses.

Corrosion increased to a maximum on the upper surface at an angle of approximately 30° from the vertical. Corrosion on the underside showed a minimum at the horizontal.

The smaller nature of the fourth quadrant of the graph as compared with the first is an indication of the dependency of the rate of corrosion on the position of the panel in the box relative to the principal direction of flow of fog. Panels with their principal surface exposed to the horizontal as well as vertical impingement of salt fog particles are subject to greater corrosion than those whose principal surface is shielded from the horizontal component.

Conclusions

These data constitute a measure of the dependency of the rate of corrosion on the angle of exposure and its relationship to the direction of the principal flow of fog in the test cabinet. They show the importance of proper consideration of the angle of exposure in salt spray testing.

APPENDIX A

TEST NUMBER 20 CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

VARIABLE - Angle of Exposure

MATERIAL - Steel

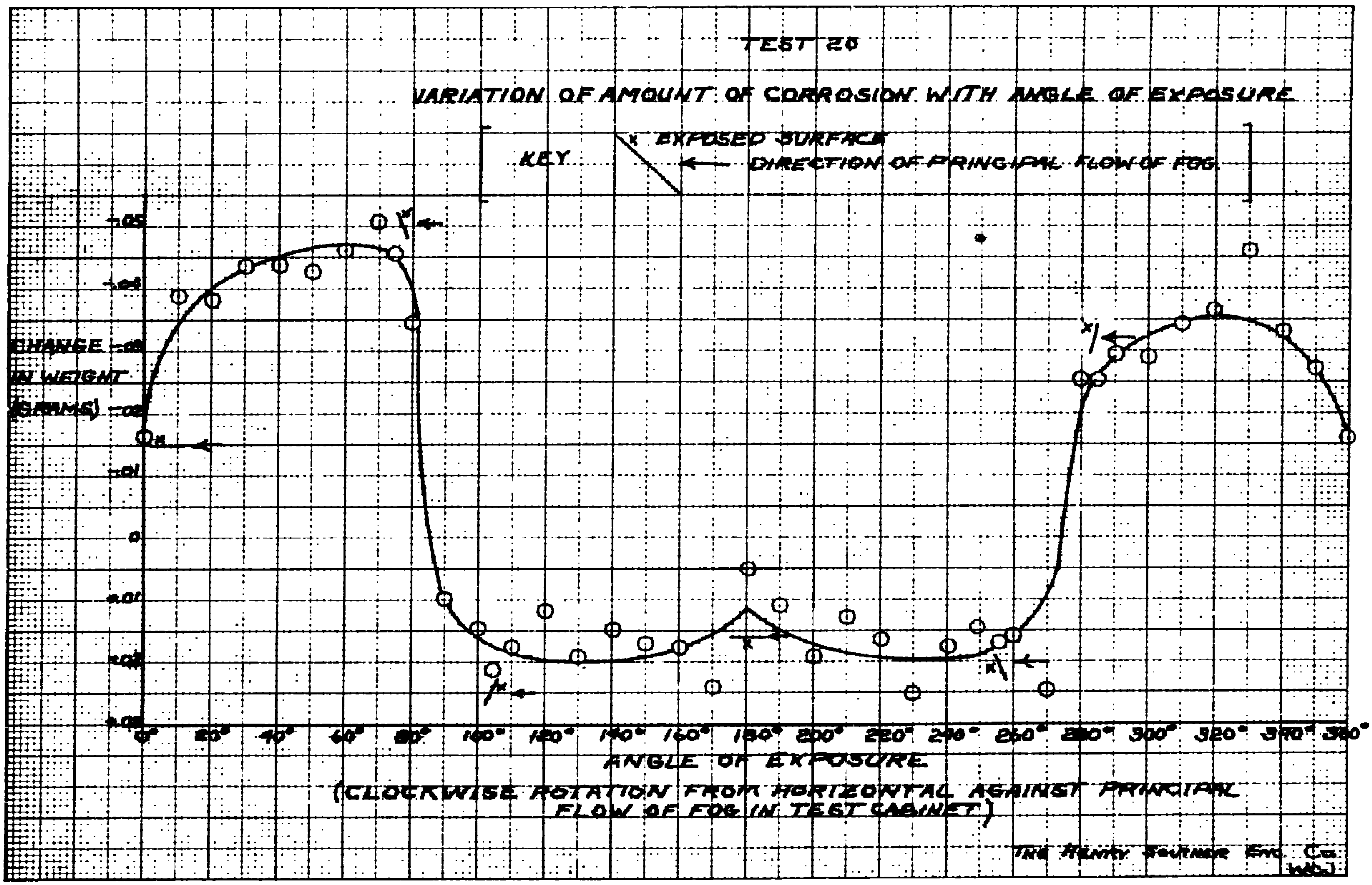
LENGTH OF TEST - 24 hours

ANGLE OF EXPOSURE	WEIGHT LOSS -grams
0°	-.0171
10°	-.0398
20°	-.0387
30°	-.0448
40°	-.0443
50°	-.0438
60°	-.0475
70°	-.0513
75°	-.0462
80°	-.0357
90°	.0084
100°	.0136
106°	.0205
110°	.0164
120°	.0107
130°	.0184
140°	.0134
150°	.0167
160°	.0238
170°	.0046
180°	.0099
190°	.0186
200°	.0116
210°	.0152
220°	.0241
230°	.0167
240°	.0132
250°	.0161
260°	.0147
270°	.0236
280°	-.0267
285°	-.0267
290°	-.0307
300°	-.0301
310°	-.0361
320°	-.0377
330°	-.0477
340°	-.0346
350°	-.0289

CONDITIONS OF TEST

Solution Composition	20% NaCl	pH of Solution	7.0
Dry Bulb Temp.(° F.)	95°	pH of Fog	7.0
Wet Bulb Temp.(° F.)	95°	Rate of Fog	
Relative Humidity	100%	Collection(mls./hr.)	1.0
Particle Size (microns)	.5	Impurities in Salt Solution	
Rate of Settling (mm./sec.)	4×10^{-6}	1. Assay	99.8%
		2. Br and I	——
Air Pressure (lbs./in.^{2})	11.5	3. Heavy Metals	——
		Specific Gravity of Solution	1.150
Room Temp.(° F.)	95°		
Rate of Flow (ft.^{3}/min.)	.46	Volume of Solution in Reservoir	5 gal.

APPENDIX B



TEST 20
VARIATION OF AMOUNT OF CORROSION WITH ANGLE OF EXPOSURE
KEY
x EXPOSED SURFACE
← DIRECTION OF PRINCIPAL FLOW OF FOG.
CHANGE IN WEIGHT (GRAMS)
-.05
-.04
-.03
-.02
-.01
0
+.01
+.02
+.03
0°
20°
40°
60°
80°
100°
120°
140°
160°
180°
200°
220°
240°
260°
280°
300°
320°
340°
360°
ANGLE OF EXPOSURE
(CLOCKWISE ROTATION FROM HORIZONTAL AGAINST PRINCIPAL FLOW OF FOG IN TEST CABINET)

APPENDIX C

TEST NO. 21

Object

The object of this test is to determine the effect of a substantial reduction of the surface tension of the test solution on the rate of corrosion in the salt spray method of accelerated corrosion testing.

Summary

A test has been conducted at 95°F, using a 20% sodium chloride solution, pH 7.0, for a period of 150 hours in the salt spray test cabinet. The surface tension of the solution used to generate the fog was reduced to approximately half its usual value by the addition of an organic wetting agent.

Introduction

The surface tension of a liquid is a measure of its cohesive nature. Liquids with high surface tensions tend to form droplets on a surface rather than an evenly distributed film as liquids of lower surface tension would. The surface tension of the salt spray test solution, therefore, is of primary importance in determining the "wettability" of the solution and should directly affect the rate of corrosion. The results of this test will be compared with those of Tests No. 7 and No. 19 to determine the effect of surface tension on the rate of corrosion.

Procedure

A procedure similar to that outlined in Test No. 7 was followed. The test was run for a period of 150 hours at 95°F, using a 20% sodium chloride solution, pH 7.0. The surface tension was lowered from a normal value of 64 dynes per centimeter to 37 dynes per centimeter by the addition of a water solution of Aerosol OT wetting agent (manufactured by American Cyanamid Corp.) Surface tensions were measured with a stalagmometer at 25°C. A summary of the operating conditions, cumulative weight losses and panel ratings appears in Appendix A while a plot of the cumulative weight losses for the steel, brass, zinc and cadmium panels comprises Appendix B.

Discussion

The steel panels lost weight at a reasonably steady rate and the weight losses showed their usual dependency on a position in the box.

The brass panels, after initial losses, gained weight steadily as has been previously experienced.

The zinc panels showed unusually high weight losses, while the cadmium panels lost weight at a steady rate in a closely grouped pattern.

The pentrated steel panels all failed before 1 hour's exposure, three failing before 1/2 hour.

The aluminum panels anodized by the chromic acid process showed a definite superiority over those prepared by the sulphuric acid process. The sulphuric acid panels all failed before 24 hours, while at the end of 66 hours, none of the chromic acid panels showed signs of attack.

The nickel plated steel panels all failed before 5 hours, one panel failing at the end of 1-1/2 hours. The phosphated steel panels all failed before 1-1/2 hours exposure.

Conclusions

These data constitute a measure of the corrosion rate, using a test solution of lowered surface tension and will be compared with the results from Tests No. 7 and No. 19 to evaluate its effect on the various types of panels used in this series of tests.

APPENDIX A

TEST NUMBER 21

CORROSION RATES AT 95° F., 20% SODIUM CHLORIDE, pH 7.0

VARIABLE - Surface tension - 37 dynes/cm.

LENGTH OF TEST - 180 hours

DATES	5/1/52	5/2/52	5/3/52	5/4/52	5/5/52	5/6/52	5/7/52
Solution Composition	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl	20% NaCl
Dry Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Wet Bulb Temp.(° F.)	95°	95°	95°	95°	95°	95°	95°
Relative Humidity	100%	100%	100%	100%	100%	100%	100%
Particle Size (microns)	.5	.5	.5	.5	.5	.5	.5
Rate of Settling (mm./sec.)	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}	4×10^{-6}
Air Pressure (lbs./in.^{2})	12	12	12	12	12	12	12
Room Temp. (° F.)	95°	95°	95°	95°	95°	95°	95°
Rate of Flow (ft.^{3}/min.)	.46	.46	.46	.46	.46	.46	.46
pH of Solution	7.0	7.0	7.0	7.0	7.0	7.0	7.0
pH of Fog	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Rate of Fog Collection (mls./hr.)	.9	1.7	1.0	1.0	1.0	1.1	1.1
Impurities in Salt Solution							
1. Assay	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%	99.8%
2. Br and I	—	—	—	—	—	—	—
3. Heavy Metals	—	—	—	—	—	—	—
Specific Gravity of Solution	1.150	1.150	1.150	1.150	1.150	1.150	1.150
Volume of Solution in Reservoir	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.	5 gal.

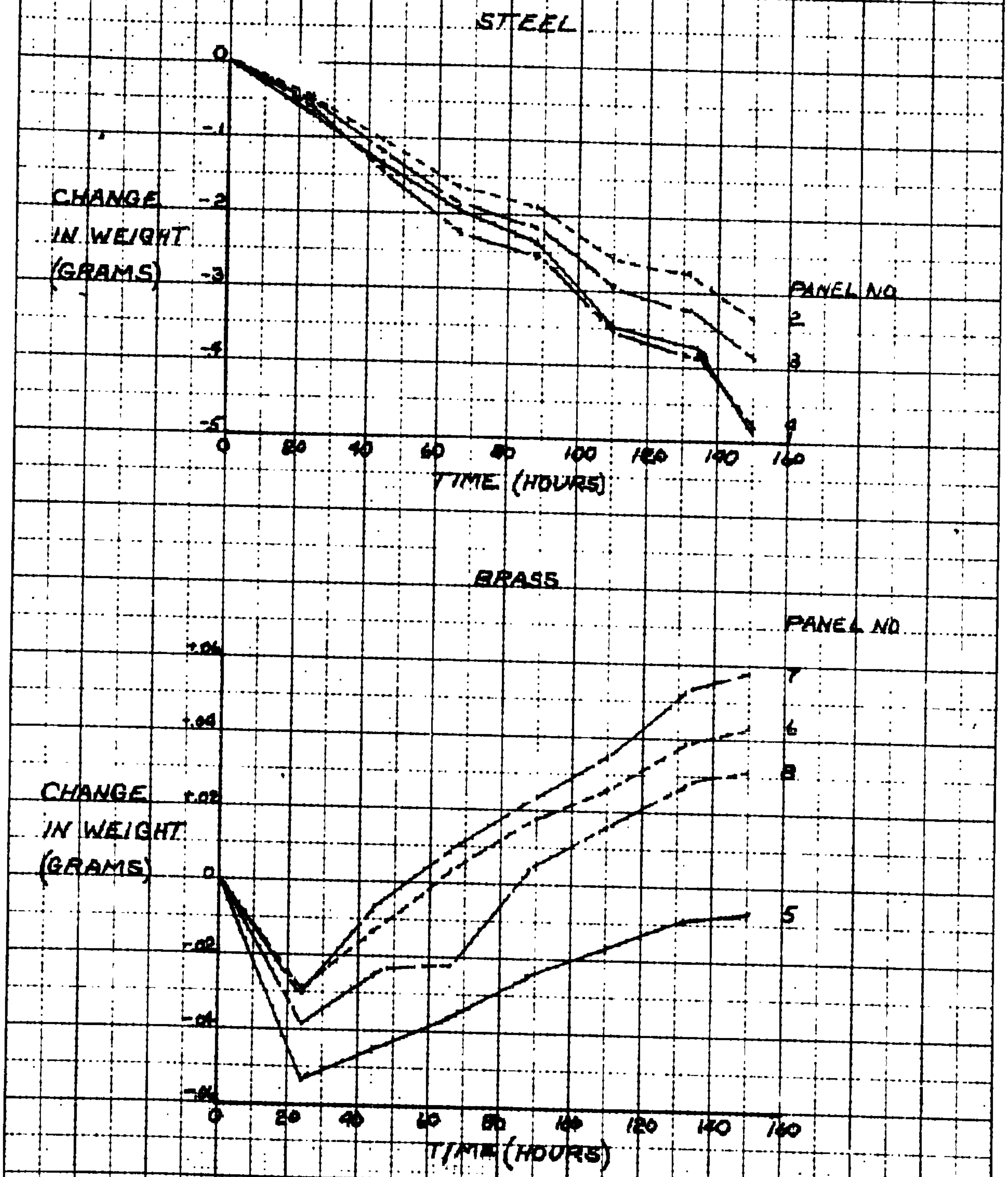
PANEL NUMBER	1/2 hr.	1 hr.	1.5 hrs.	2 hrs.	5 hrs.	24 hrs.	44 hrs.	66 hrs.	98 hrs.	110 hrs.	132 hrs.	180 hrs.
Steel												
1						.0647	.1334	.1995	.2356	.3490	.3714	.4678
2						.0450	.1033	.1652	.1996	.2532	.2709	.3360
3						.0486	.1206	.1970	.2186	.2964	.3209	.3872
4						.0589	.1418	.2223	.2553	.3820	.3640	.4664
Brass												
5						.0535	.0460	.0362	.0244	.0168	.0097	.0068
6						.0287	.0134	-.0059	-.0163	-.0260	-.0381	-.0429
7						.0251	.0069	-.0062	-.0221	-.0646	-.0623	-.0660
8						.0563	.0249	.0224	-.0041	-.0186	-.0272	-.0309
Zinc												
9						.1368	.2891	.5008	.5606	.8679	.9865	1.1657
10						.2054	.3208	.4954	.5555	.8701	.9995	1.3069
11						.1541	.3446	.6376	.6614	.9425	1.0564	1.1967
12						.1177	.2867	.5582	.5711	.5501	.9482	1.1754
Cadmium												
13						.0649	.1060	.1438	.1922	.2381	.2942	.3212
14						.0628	.1158	.1560	.2012	.2452	.3015	.3261
15						.0457	.0817	.1296	.1777	.2033	.2363	.2496
16						.0437	.0983	.1440	.1997	.2261	.2596	.2741
Pentrated Steel												
17	Failed											
18	Failed											
19	10/10											
20	Failed											
Anodized Aluminum (H_2SO_4)												
21						Failed						
22						Failed						
23						Failed						
24						Failed						
Anodized Aluminum (CrO_3)												
25						10/10	10/10	10/10	3.7/4/9	Failed		
26						10/10	10/10	10/10	10/10	Failed		
27						10/10	10/10	10/10	2.3/4/9	Failed		
28						10/10	10/10	10/10	10/10	6.5/4/9	6.5/4/9	6.5/4/9
Nickel-plated Steel												
29	10/10	10/10	10/10	10/10	Failed							
30	10/10	10/10	10/10	10/10	Failed							
31	10/10	10/10	Failed									
32	10/10	10/10	10/10	10/10	Failed							
Phosphated Steel												
33	10/10	10/10	Failed									
34	10/10	10/10	Failed									
35	10/10	10/10	Failed									
36	10/10	10/10	Failed									

APPENDIX B

TEST 21

WEIGHT LOSSES AT 95°F 20% SODIUM CHLORIDE, pH 7.0

SURFACE TENSION REDUCED TO 37 DYNES/CM.



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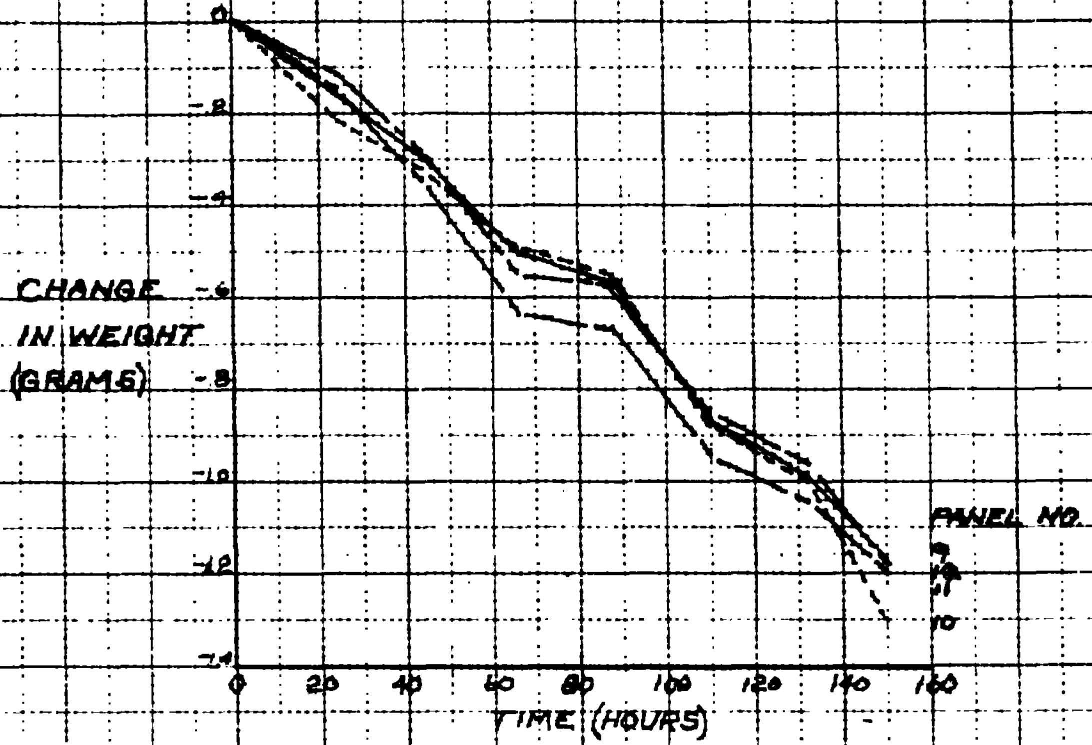
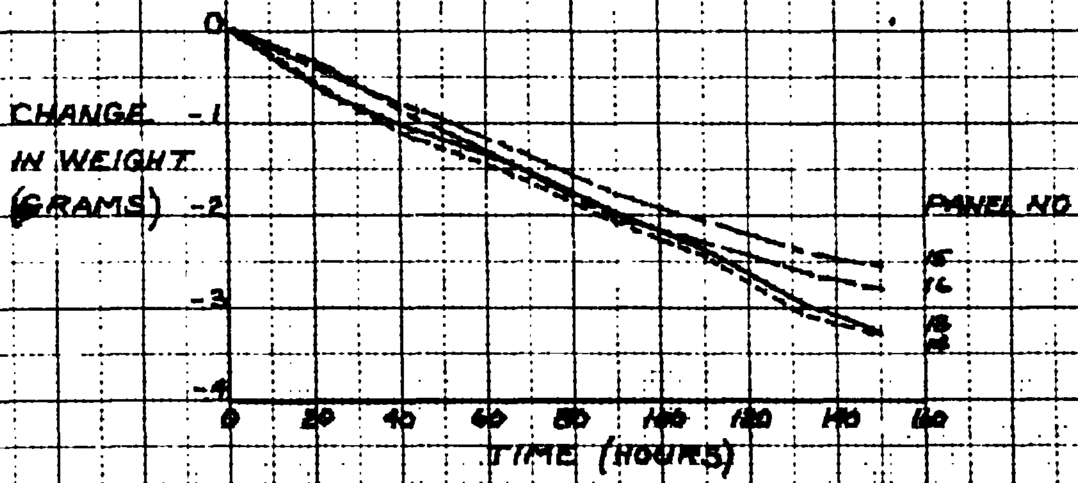
TEST 21

WEIGHT LOSSES AT 95°F, 20% SODIUM CHLORIDE, pH 7.0
SURFACE TENSION REDUCED TO 37 DYNES/CM

ZINC



CADMIUM



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TEST NO. 22

Object

The object of this test is to determine the corrosive effects of a marine atmosphere on the various types of test panels used in the salt spray investigation.

Summary

An outdoor test has been conducted at Westbrook, Connecticut on the steel, brass, zinc, cadmium, pentrated, steel, anodized aluminum, nickel plated steel and phosphated steel panels used in the foregoing series of salt spray tests. This test in a marine atmosphere will be used in comparison with exposure tests made in an industrial atmosphere as well as salt spray and humidity tests.

Introduction

A frequent and possibly well grounded criticism of the salt spray test is that it does not duplicate actual conditions of exposure in service. Furthermore, it has been stated that comparisons between salt spray results and marine exposure tests show less correlation than with results of exposure tests made in non-marine atmospheres. The type of corrosion is said to be different in each case as evidenced by a different character of products obtained in the corrosion of nickel plated steel panels. This test, therefore, is an attempt to measure the possible agreements and disagreements between salt spray and marine exposure tests.

Procedure

A full set of thirty-six panels, four each of the nine different types, were cleaned and prepared according to methods described in Test No. 7. A special rack was constructed so as to incline the panels at an angle of 30° from the vertical. The panels were supported on both top and bottom by slotted racks which were securely fastened to prevent removal by sudden gusts of wind. The whole assembly was secured to the roof by sandbags. The panels were so situated that their major surface was parallel to the shore and exposed in a general southerly direction. This test was conducted at Westbrook, Connecticut and the panels were approximately 150 feet from high water.

A summary of observations and times of exposure are shown in Appendix A.

The steel, brass, zinc and cadmium panels were cleaned according to the usual methods after 1,032 hours exposure and reweighed. The weight losses computed also appear in Appendix A.

Discussion

The observations made at the various times throughout the test are self-explanatory. It is interesting to note, however, the somewhat apparent superiority of the anodized aluminum panels over those prepared by the sulphuric acid process.

The total weight losses after 1,032 hours exposure for the cadmium panels are of the same order as those obtained in the first 24 hours of salt spray exposure. This would indicate the inertness and tenaciousness of the protective oxide film that forms.

The very slight weight changes of the brass panels also show the protective nature of the initial corrosion products.

Conclusions

These data are a measure of the corrosive effects of a marine atmosphere, and will be used in comparison with outdoor exposure tests in an industrial atmosphere and salt spray tests to determine any possible correlation between the three.

APPENDIX A

TEST NUMBER 22

ANGLE OF EXPOSURE - 30° from the vertical

SEA ATMOSPHERE EXPOSURE TEST: WESTBROOK, CONNECTICUT
DISTANCE FROM HIGH WATER - 150 feet

PANEL NUMBER	168 hours	480 hours	618 hours	840 hours	1032 hours	WEIGHT LOSS (grams)
Steel						
1	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	-.2088
2	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	-.2123
3	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	-.2062
4	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	-.2078
Brass						
5	Slight green tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	-.0006
6	Slight green tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	.0014
7	Slight green tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	.0040
8	Slight green tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	Heavy green-brown tarnish	.0000
Zinc						
9	White corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	-.0810
10	White corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	-.0408
11	White corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	-.0258
12	White corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	Heavy white corrosion	-.0920
Cadmium						
13	Loss of lustre	Loss of lustre-no corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0110
14	Loss of lustre	Loss of lustre-no corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0128
15	Loss of lustre	Loss of lustre-no corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0094
16	Loss of lustre	Loss of lustre-no corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0135
Pentrated Steel						
17	Badly rusted (50%)	80% covered with rust	90% covered with rust	95% covered with rust	95% covered with rust	
18	Badly rusted (50%)	80% covered with rust	90% covered with rust	95% covered with rust	95% covered with rust	
19	Badly rusted (50%)	80% covered with rust	90% covered with rust	95% covered with rust	95% covered with rust	
20	Badly rusted (50%)	80% covered with rust	90% covered with rust	95% covered with rust	95% covered with rust	
Anodized Aluminum (H_2SO_4)						
21	No corrosion	No corrosion	No corrosion	Loss of lustre	Loss of lustre	
22	No corrosion	No corrosion	No corrosion	Loss of lustre	Loss of lustre	
23	No corrosion	No corrosion	No corrosion	No loss of lustre	Slight loss of lustre	
24	No corrosion	No corrosion	No corrosion	No loss of lustre	Slight loss of lustre	
Anodized Aluminum (CrO_3)						
25	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
26	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
27	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
28	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
Nickel-plated Steel						
29	Lustre gone-no rust	Failed				
30	Lustre gone-no rust	Failed				
31	Lustre gone-no rust	Failed				
32	Lustre gone-no rust	Failed				
Phosphated Steel						
33	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	
34	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	
[illegible]	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	
[illegible]	Badly rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	

TEST NO. 23

Object

The object of this test is to determine the corrosive effect of an industrial atmosphere on the various types of panels used in this series of tests and to correlate, if possible, the results obtained with those from salt spray, humidity and marine exposure tests.

Summary

A test has been conducted for a period of 1,190 hours on the roof of the Henry Souther Engineering Co., on the steel, brass, zinc, cadmium, enameled steel, anodized aluminum, nickel plated steel and phosphated steel panels used in this series of tests. Periodic observations were made and weight losses for the steel, brass, zinc and cadmium panels computed.

Introduction

Outdoor exposure tests have shown wide variance when compared with the results of salt spray tests on similar materials. For the purpose of comparison with results of other types of corrosion tests, this test is an attempt to measure the corrosive effects of an industrial atmosphere.

Procedure

The thirty-six panels used in the foregoing series of tests were prepared and cleaned according to methods outlined in Test No. 7. They were placed in a specially constructed rack and securely held at both top and bottom by adjustable nails. The panels were inclined at an angle of 30° from the vertical and the principal surface of the panel was directed toward the south. The whole assembly was held on the roof by sand bags. The test rack was located about 50 feet from an exhaust hood which discharges a variety of fumes, many of an acidic nature. The test was run for a period of 1,190 hours. Observations made during this time appear in Appendix A as well as the weight losses of the steel, brass, zinc and cadmium panels, determined at the end of the test.

Discussion

The periodic observations of the panels are self-explanatory. The same standards of failure were used as in the salt spray tests.

The chromic acid anodized aluminum panels showed a definite superiority over those prepared by the sulphuric acid process.

The greater weight losses experienced for the steel, brass, zinc and cadmium panels when compared with the results obtained from the marine exposure test could be due to the corrosive nature of the fumes from the adjacent exhaust fan.

Conclusions

The results obtained in this test will be used as a measure of the corrosiveness of an industrial atmosphere for the purpose of comparison with results obtained from other types of corrosion tests herein described.

APPENDIX A

TEST NUMBER 25

OUTDOOR EXPOSURE TEST, INDUSTRIAL ATMOSPHERE

ANGLE OF EXPOSURE - 30° from the vertical
Significant surface exposed to the south

PANEL NUMBER	48 hours	168 hours	552 hours	850 hours	998 hours	1190 hours	WEIGHT LOSS (grams)
Steel							
1	50% rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	.8962
2	50% rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	1.1066
3	50% rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	1.0301
4	50% rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	Completely rusted	1.1325
Brass							
5	General darkening	Increased darkening	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	.0255
6	General darkening	Increased darkening	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	.0251
7	General darkening	Increased darkening	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	.0256
8	General darkening	Increased darkening	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	Dark green-brown tarnish	.0259
Zinc							
9	Very slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	.0431
10	Very slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	.0473
11	Very slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	.0505
12	Very slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	Slight white corrosion	.0529
Cadmium							
13	No corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0650
14	No corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0593
15	No corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0682
16	No corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	Slight grey corrosion	.0754
Enameled Steel							
17	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
18	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
19	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
20	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
Anodized Aluminum (H_2SO_4)							
21	No corrosion	No corrosion	No corrosion	Failed			
22	No corrosion	No corrosion	No corrosion	Failed			
23	No corrosion	No corrosion	No corrosion	Failed			
24	No corrosion	No corrosion	No corrosion	No corrosion	Failed		
Anodized Aluminum (CrO_3)							
25	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
26	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
27	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
28	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	No corrosion	
Nickel-plated Steel							
29	General mottled appearance	Failed					
30	General mottled appearance	Failed					
31	General mottled appearance	Failed					
32	General mottled appearance	Failed					
Phosphated Steel							
33	No rusting	Failed					
34	No rusting	Failed					
35	No rusting	Failed					
36	No rusting	Failed					

TEST NO. 24

Object

The object of this test is to determine the effects of humidity cabinet exposure on the steel, brass, zinc, cadmium, pentrated steel, anodized aluminum, nickel plated steel and phosphated steel panels used in the foregoing series of salt spray and outdoor exposure tests.

Summary

A test has been conducted in the humidity cabinet for a period of 976 hours at 100°F and a relative humidity of 95%. Weight losses were measured and panels rated according to the same system as used in the salt spray tests.

Introduction

Humidity cabinet exposure tests would be a possible substitution for salt spray as a method of accelerated corrosion testing. The effect of a humid atmosphere on the various types of panels used in this series of tests should be determined in order that possible comparisons might be made between this method and salt spray and outdoor exposure tests.

Procedure

The thirty-six panels used in this series of tests were prepared according to methods outlined in Test No. 7. Details of construction of the humidity cabinet appear in Phase II of this report. A special wood rack was constructed to support the individual panel holders. The panels were placed in the box in a random distribution as shown in Appendix A. The temperature was maintained at 100°F and the relative humidity adjusted to a minimum value of 95%. The test was conducted for a period of 976 hours during which time daily observations were made and weight losses determined. A summary of these observations and weight losses for the steel, brass, zinc and cadmium appears in Appendix B, while a plot of these weight losses comprises Appendix C.

Discussion

The steel panels lost weight in a rather irregular pattern although the overall picture is one of a steady weight loss. Corrosion products obtained were of the same character as those in outdoor exposure tests or those experienced on the underside of panels in salt spray tests; that is, the products were dark, fine-grained and difficult to remove by scrubbing.

The brass panels gained weight in a highly irregular day to day variation. The general tendency was an approach to a constant value in excess of the original weight.

The zinc panels gained weight steadily and in a fairly closely grouped pattern. The tendency again was to approach a steady value that is in excess of the original weight.

The cadmium panels showed the largest weight losses which was probably due to the fact that this was the only series of panels in which complete removal of the corrosion products could be accomplished (i.e. cyanide cleaning).

The pentrated steel panels all failed before 24 hours exposure.

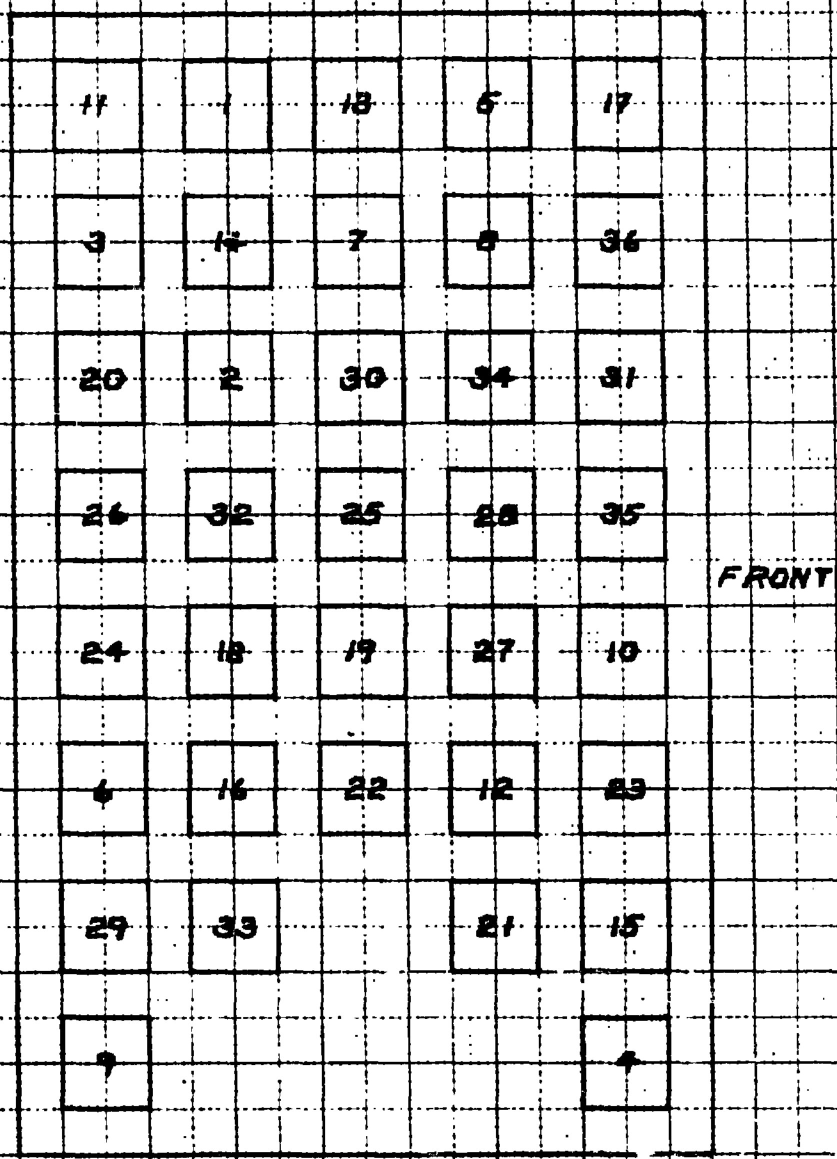
The sulphuric acid anodized aluminum panels proved superior to those prepared by the chromic acid process. The sulphuric acid panels snowed no signs of failure at the end of the test (976 hours), while three of the chromic acid anodized panels failed after 576 hours exposure.

The nickel plated steel panels all failed before 72 hours exposure as did the phosphated steel panels.

Conclusions

These data constitute a measure of the corrosive effects of a humid atmosphere on the test panels under observation and will be used in comparison with the results from salt spray and outdoor exposure tests to evaluate the effectiveness of humidity cabinet exposure as a method of accelerated corrosion testing.

APPENDIX A



PLOT SHOWING RANDOM
DISTRIBUTION OF PANELS
IN HUMIDITY CABINET

The Henry Souther Eng. Co.

APPENDIX B

TEST NUMBER 24

HUMIDITY CABINET TEST: RELATIVE HUMIDITY 98%, 100° F.

CUMULATIVE WEIGHT LOSSES

Hours

PANEL NO.	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600	624	648
Steel																											
1	-.0015	.0024	-.0138	-.0072	-.0035	.0072	.0135	.0211	.0248	.0409	.0479	.0537	.0602	.0929	.1246	.1354	.1549	.1823	.1702	.1845	.1979	.2099	.2208	.2230	.2286	.2251	.2348
2	.0001	.0005	-.0048	-.0072	-.0054	-.0027	-.0009	.0078	.0144	.0258	.0338	.0414	.0478	.0563	.0854	.1040	.1274	.1410	.1666	.1765	.1889	.2097	.2208	.2322	.2410	.2358	.2387
3	.0000	.0003	-.0049	-.0053	-.0034	.0158	.0175	.0584	.0590	.0765	.0859	.0966	.1043	.1212	.1501	.1768	.1973	.2227	.2310	.2559	.2819	.3095	.3269	.3295	.3180	.3421	.3461
4	-.0051	-.0032	.0002	.0706	.0186	.0192	.0777	.1143	.1119	.1158	.1118	.1157	.1400	.1370	.2113	.2839	.2970	.3061	.3121	.3500	.3348	.3436	.3383	.3536	.3229	.3598	.4154
Brass																											
5	.0041	-.0096	-.0114	-.0112	-.0103	-.0039	-.0144	-.0145	-.0139	-.0120	-.0121	.0140	-.0165	-.0159	-.0158	-.0156	-.0169	-.0180	-.0192	-.0196	-.0197	-.0139	-.0185	-.0186	-.0241	-.0166	-.0202
6	.0024	-.0052	-.0064	-.0091	-.0047	0.0028	-.0082	-.0002	-.0052	-.0064	-.0092	-.0089	-.0099	-.0107	-.0112	-.0115	-.0118	-.0207	-.0145	-.0181	-.0162	-.0150	-.0133	-.0165	-.0205	-.0136	-.0159
7	.0053	-.0026	-.0056	-.0056	-.0054	-.0013	-.0076	-.0102	-.0060	-.0048	-.0071	-.0090	-.0091	-.0082	-.0110	-.0132	-.0092	-.0123	-.0130	-.0119	-.0134	-.0124	-.0149	-.0141	-.0494	-.0134	-.0153
8	.0016	-.0009	-.0055	-.0069	-.0068	-.0072	-.0099	-.0134	-.0172	-.0099	-.0813	-.0111	-.0120	-.0102	-.0134	-.0150	-.0124	-.0148	-.0157	-.0159	-.0171	-.0138	-.0152	-.0157	-.0171	-.0169	-.0222
Zinc																											
9	-.0161	-.0854	-.0862	-.1046	-.1216	-.1313	-.1420	-.1520	-.1586	-.1640	-.1715	-.1761	-.1830	-.1960	-.1872	-.1987	-.1947	-.1959	-.1995	-.2020	-.2056	-.2019	-.2018	-.2074	-.2059	-.2090	-.2190
10	-.0089	-.0149	-.0846	-.0556	-.0937	-.0954	-.1101	-.1286	-.1340	-.1388	-.1496	-.1541	-.1610	-.1614	-.1653	-.1671	-.1683	-.1691	-.1734	-.1756	-.1783	-.1758	-.1756	-.1835	-.1825	-.1860	-.1939
11	-.0170	-.0264	-.0478	-.0615	-.0902	-.0969	-.0802	-.1320	-.1425	-.1479	-.1567	-.1648	-.1711	-.1762	-.1811	-.1811	-.1864	-.1892	-.1950	-.1990	-.2039	-.1937	-.2007	-.2070	-.2064	-.2070	-.2194
12	-.0076	-.0196	-.0514	-.0752	-.1010	-.1157	-.1324	-.1431	-.1568	-.1664	-.1734	-.1797	-.1902	-.1918	-.1922	-.1927	-.1961	-.1973	-.2001	-.2048	-.2103	-.2044	-.2106	-.2174	-.2210	-.2214	-.2324
Cadmium																											
13	.0069	.0154	.0241	.0320	.0404	.0456	.0704	.0806	.0914	.1044	.1132	.1326	.1424	.1513	.1673	.1750	.1853	.1933	.1978	.2080	.2253	.2386	.2510	.2631	.2919	.3135	.3212
14	.0038	.0125	.0253	.0335	.0441	.0596	.0785	.1058	.1148	.1290	.1470	.1924	.2010	.2082	.2194	.2278	.2365	.2461	.2653	.2619	.2912	.3094	.3470	.3604	.3728	.3799	.3878
15	.0050	.0100	.0297	.0394	.0563	.0722	.0907	.1230	.1639	.2048	.2473	.2588	.3221	.3305	.3389	.3489	.3699	.3817	.3969	.4105	.4573	.4955	.5453	.5775	.6074	.6198	.6295
16	.0056	.0127	.0326	.0447	.0612	.0786	.1131	.1501	.1688	.1902	.2240	.2556	.2934	.3010	.3210	.3345	.3562	.3695	.3778	.3894	.4288	.4444	.4852	.5161	.5514	.5635	.5727
Pentrated Steel																											
17	Failed																										
18	Failed																										
19	Failed																										
20	Failed																										
Anodized Aluminum (H_2SO_4)																											
21	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
22	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
23	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
24	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)																											
25	10/10	10/10	10/10	10/10	10/10	9/d/9	9/d/9	9/d/9	8/d/9	8/d/9	3.3/d/9	same	same	same	same	same	same	same	same	same	same	same	same	Failed			
26	10/10	10/10	10/10	10/10	10/10	9/d/9	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same	same
27	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	2.5/d/9	same	same	same	same	same	same	same	same	same	same	same	same	Failed			
28	10/10	10/10	10/10	10/10	10/10	10/10	9/3/9	same	same	same	3.3/d/9	same	same	same	same	same	same	same	same	same	same	same	same	Failed			
Nickel-plated Steel																											
29	10/10	10/10	Failed																								
30	10/10	Failed																									
31	10/10	10/10	Failed																								
32	Failed																										
Phosphated Steel																											
33	10/10	Failed																									
34	10/10	10/10	Failed																								
35	Failed																										
36	Failed																										

HUMIDITY CABINET TEST: RELATIVE HUMIDITY 98%, 100° F.

CUMULATIVE WEIGHT LOSSES

Hours

	336	360	384	408	432	456	480	504	528	552	576	600	624	648
Steel														
	.0929	.1244	.1554	.1549	.1625	.1702	.1845	.1979	.2099	.2208	.2230	.2286	.2231	.2345
	.0563	.0854	.1043	.1274	.1410	.1568	.1765	.1589	.2097	.2208	.2522	.2410	.2558	.2387
	.1212	.1501	.1766	.1973	.2227	.2310	.2639	.2818	.3095	.3269	.3295	.3180	.3421	.3461
	.1370	.2113	.2839	.2970	.3061	.3121	.3300	.3348	.3436	.3383	.3336	.3229	.3398	.4154
Brass														
	-.0159	-.0158	-.0156	-.0169	-.0150	-.0152	-.0198	-.0197	-.0139	-.0185	-.0186	-.0241	-.0166	-.0202
	-.0107	-.0112	-.0115	-.0118	-.0207	-.0145	-.0151	-.0162	-.0150	-.0133	-.0163	-.0205	-.0138	-.0159
	-.0082	-.0110	-.0132	-.0082	-.0123	-.0130	-.0119	-.0134	-.0124	-.0148	-.0141	-.0494	-.0134	-.0153
	-.0102	-.0134	-.0150	-.0124	-.0148	-.0157	-.0159	-.0171	-.0138	-.0152	-.0157	-.0171	-.0169	-.0222
Zinc														
	-.1860	-.1872	-.1987	-.1947	-.1959	-.1995	-.2020	-.2056	-.2019	-.2018	-.2074	-.2059	-.2090	-.2190
	-.1614	-.1658	-.1671	-.1683	-.1691	-.1734	-.1756	-.1783	-.1788	-.1756	-.1838	-.1825	-.1860	-.1939
	-.1762	-.1811	-.1811	-.1884	-.1892	-.1950	-.1990	-.2059	-.1937	-.2007	-.2070	-.2064	-.2070	-.2194
	-.1918	-.1922	-.1927	-.1961	-.1975	-.2001	-.2048	-.2103	-.2044	-.2106	-.2174	-.2210	-.2214	-.2124
Cadmium														
	.1513	.1673	.1750	.1853	.1933	.1978	.2080	.2253	.2386	.2510	.2631	.2919	.3133	.3212
	.2082	.2194	.2278	.2365	.2461	.2553	.2619	.2912	.3094	.3470	.3604	.3728	.3783	.3878
	.3303	.3389	.3439	.3690	.3817	.3969	.4105	.4373	.4955	.5453	.5775	.6074	.6192	.6295
	.3010	.3210	.3345	.3562	.3695	.3778	.3894	.4288	.4444	.4952	.5161	.5514	.5633	.5727
Pentrated Steel														
Anodized Aluminum (H_2SO_4)														
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10
Anodized Aluminum (CrO_3)														
	same	same	same	same	same	same	same	same	same	same	Failed			
	same	same	same	same	same	same	same	same	same	same	same	same	same	same
	same	same	same	same	same	same	same	same	same	same	Failed			
	same	same	same	same	same	same	same	same	same	same	Failed			
Nickel-plated Steel														
Phosphated Steel														

	672	696	720	744	760	784	804	828	852	876	900	924	948	976
Steel														
	.2413	.2583	.2558	.2598	.2692	.2765	.2875	.2[illegible]	.2921	.2963	.3055	.3106	-.3029	-.2975
	.2595	.2630	.2743	.2332	.2962	.2989	.3052	.3215	.3325	.3415	.3469	.3519	-.3499	-.3527
	.3840	.4030	.4266	.4206	.4219	.4328	.4331	.4377	.4470	.4508	.4576	.4544	-.4617	.4633
	.4522	.4866	.5237	.5308	.5411	.5438	.5614	.5497	.5553	.5475	.5466	.5479	.5478	.5465
Brass														
	-.0203	-.0205	-.0206	-.0208	-.0219	-.0207	-.0220	-.0196	-.0204	-.0197	-.0198	-.0219	-.0199	-.0224
	-.0175	-.0177	-.0134	-.0194	-.0174	-.0183	-.0185	-.0150	-.0156	-.0144	-.0144	-.0190	-.0166	-.0184
	-.0129	-.0168	-.0152	-.0154	-.0176	-.0158	-.0162	-.0123	-.0148	-.0145	-.0138	-.0162	-.0185	-.0179
	-.0192	-.0136	-.0211	-.0211	-.0209	-.0133	-.0225	-.0207	-.0228	-.0200	-.0198	-.0228	-.0207	-.0224
Zinc														
	-.2208	-.2199	-.2223	-.2238	-.2246	-.2283	-.2306	-.2333	-.2367	-.2405	-.2400	-.2481	-.2517	-.2561
	-.1931	-.1938	-.1938	-.1955	-.1974	-.2000	-.2081	-.2026	-.2068	-.2118	-.2098	-.2198	-.2221	-.2331
	-.2186	-.2182	-.2214	-.2227	-.2270	-.2104	-.2343	-.2373	-.2402	-.2447	-.2434	-.2547	-.2566	-.2655
	-.2365	-.2372	-.2398	-.2408	-.2410	-.2463	-.2489	-.2527	-.2583	-.2647	-.2627	-.2711	-.2740	-.2846
Cadmium														
	.3353	.3530	.3721	.3870	.3945	.4114	.4236	.4327	.4311	.4510	.4661	.4967	.5047	.5093
	.3880	.4076	.4371	.4516	.4489	.4710	.4888	.5083	.5147	.5262	.5624	.5046	.6175	.6305
	.6359	.6479	.6649	.6358	.7052	.7337	.7597	.7913	.7928	.8066	.9901	.9244	.9478	.9731
	.5802	.5968	.6136	.6313	.6495	.6747	.7046	.7234	.7307	.7447	.8204	.8441	.8628	.8515
Pentrated Steel														
Anodized Aluminum (H_2SO_4)														
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/1
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/1
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/1
	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/10	10/1
Anodized Aluminum (CrO_3)														
	same	same	same	same	same	same	same	same	same	same	same	same	same	same
Nickel-plated Steel														
Phosphated Steel														

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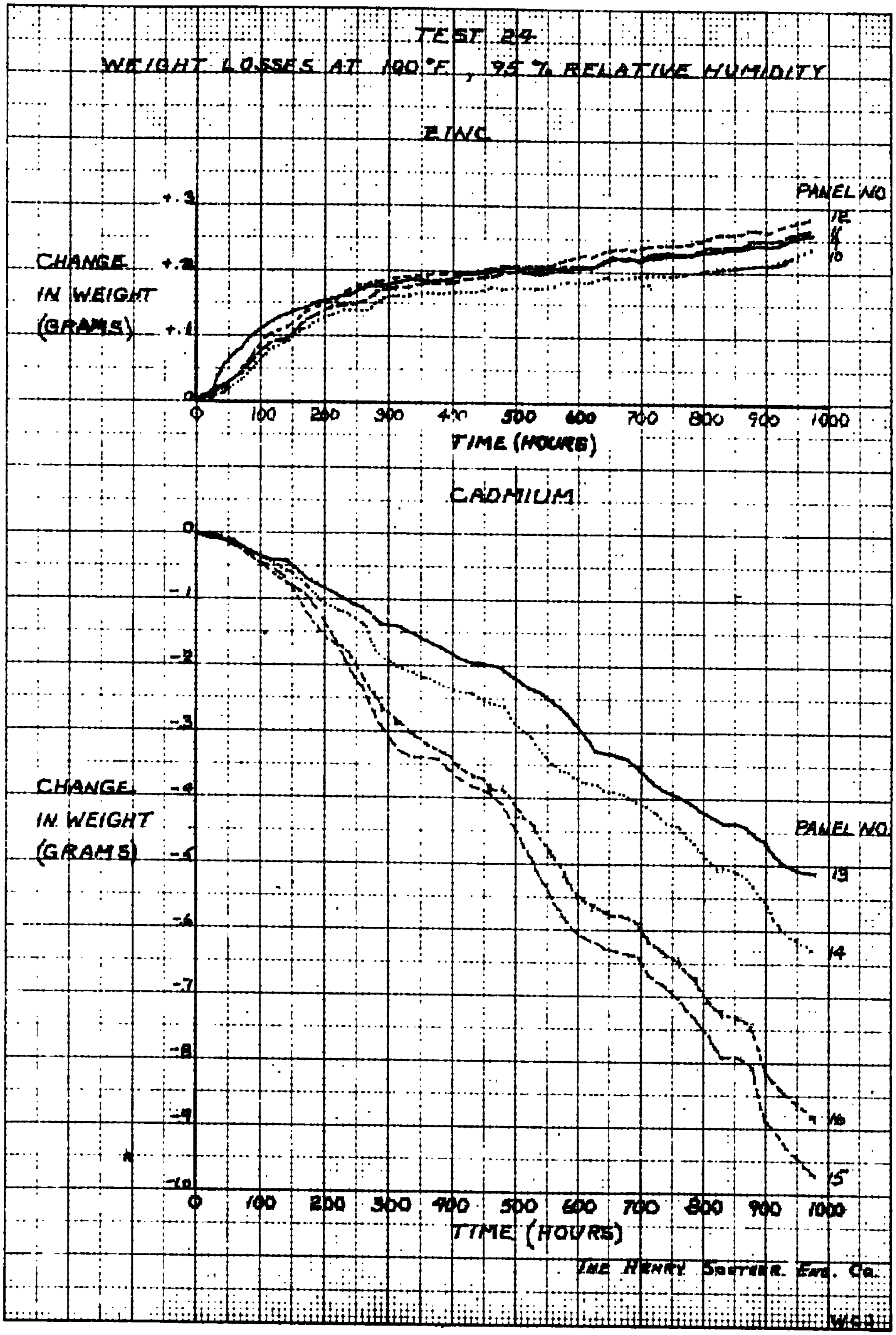
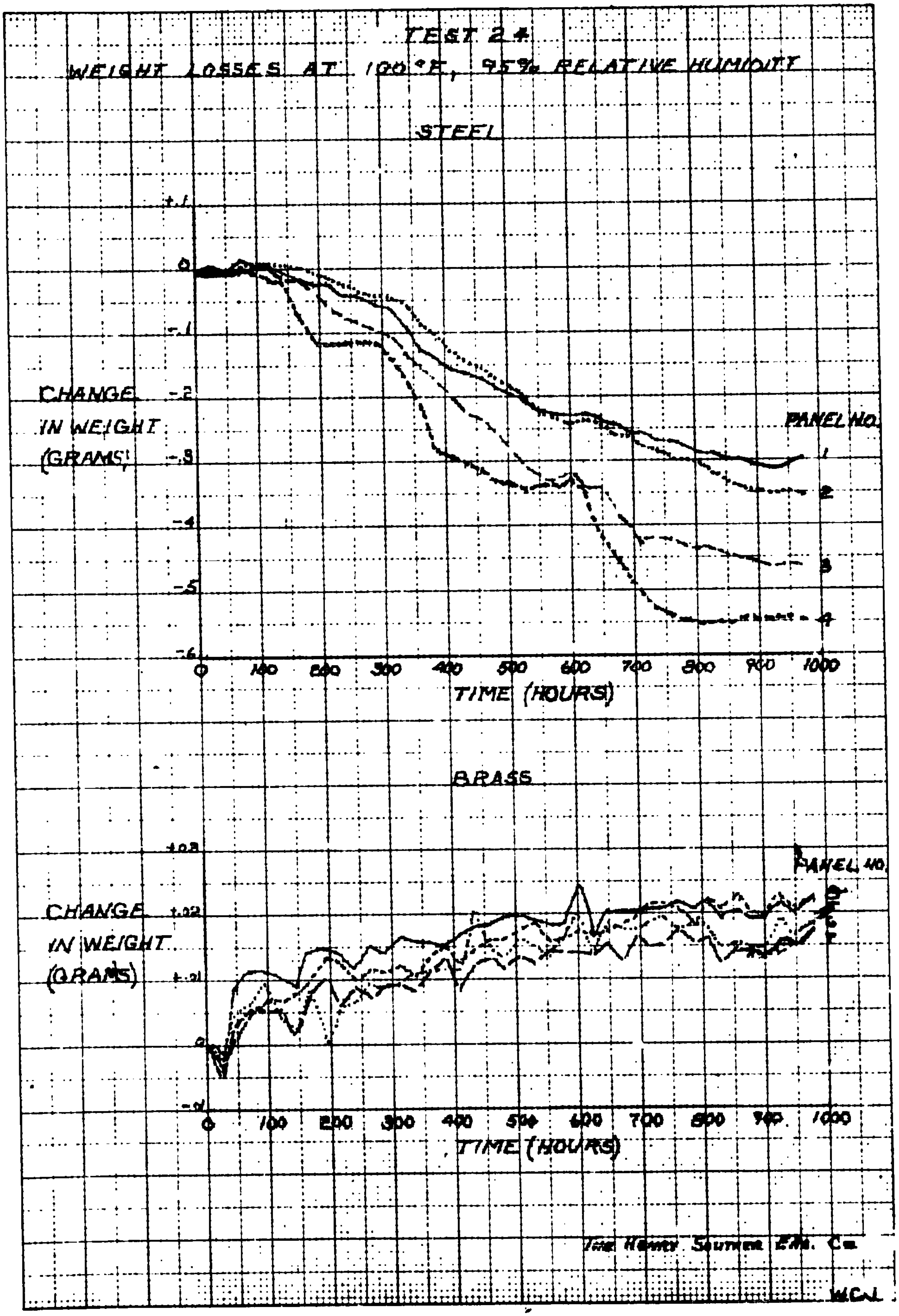
APPENDIX C


TEST 24
WEIGHT LOSSES AT 100°F, 95% RELATIVE HUMIDITY
ZINC
PANEL NO.
12
11
9
10
CHANGE IN WEIGHT (GRAMS)
+.3
+.2
+.1
0
TIME (HOURS)
0
100
200
300
400
500
600
700
800
900
1000
CADMIUM
PANEL NO.
13
14
16
15
CHANGE IN WEIGHT (GRAMS)
-.1
-.2
-.3
-.4
-.5
-.6
-.7
-.8
-.9
-1.0
TIME (HOURS)
THE HENRY SOUTHER ENG. CO.
W.C.B.


TEST 24
WEIGHT LOSSES AT 100°F, 95% RELATIVE HUMIDITY
STEEL
+.1
0
-.1
CHANGE IN WEIGHT (GRAMS)
-.2
-.3
-.4
-.5
-.6
PANEL NO.
1
2
3
4
0
100
200
300
400
500
600
700
800
900
1000
TIME (HOURS)
BRASS
+.03
+.02
+.01
0
-.01
CHANGE IN WEIGHT (GRAMS)
PANEL NO.
0
100
200
300
400
500
600
700
800
900
1000
TIME (HOURS)
The Henry Souther Eng. Co.
WCJ